THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Access management for road hauliers and rail operators in intermodal freight terminals

STEFAN JACOBSSON

Department of Technology Management and Economics

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2020

Access management for road hauliers and rail operators in intermodal freight terminals

STEFAN JACOBSSON

ISBN 978-91-7905-317-8

Doktorsavhandlingar vid Chalmers tekniska högskola
Ny serie nr 4784
ISSN 0346-718X

Division of Service Management and Logistics
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone: +46 (0) 31-772 1000

Printed by Chalmers digitaltryck
Gothenburg, Sweden 2020

Access management for road hauliers and rail operators in intermodal freight terminals

Stefan Jacobsson
Division of Service Management and Logistics
Department of Technology Management and Economics
Chalmers University of Technology

ABSTRACT

A pivotal element in the transport industry, intermodal freight transport, is rather complex due to the numerous transport modes and actors involved. Terminal operators in intermodal freight transport face major challenges to provide seamless flows of containers via their terminals. Seamless flows are achievable by bridging gaps between large-scale transport operators (e.g. shipping lines) and small-scale transport operators (e.g. road hauliers and rail operators). Effective access processes can not only bridge those gaps but also contribute to decreasing turnaround times for trucks and trains. By applying the access processes, small-scale transport operators can receive access to specific resources in terminals. An effective access process can be achieved when transport resources (e.g. trucks and truck drivers) can be managed together with terminal resources (e.g. straddle carriers and straddle carrier drivers). In this thesis, such management is termed *access management*, defined as managing the process by which actors access resources at terminals. Guided by that concept, the thesis seeks to increase the understanding of how access management for road hauliers and rail operators in intermodal freight terminals can contribute to decreasing turnaround times for trucks and trains.

The thesis is a compilation of five papers reporting studies that involved literature reviews, interviews, focus groups, participant observations and time measurements. Whereas the literature reviews focused on the topics of access management and information exchange, the collected data were analysed by implementing several analytical frameworks developed for the thesis. The results of using those frameworks clarified how effective access to resources at intermodal freight terminals can be managed, especially by explaining four dynamics: (1) how different information services can contribute to decreasing turnaround times for trucks and trains, (2) how those services can affect activity performance and resource utilisation, (3) how the required and most relevant attributes of information can be exchanged in real time among actors involved and (4) how and when such attributes need to be automatically collected and exchanged. Following from those results, the chief finding is that terminal operators can effectively manage transport and terminal processes, as well as decrease turnaround for trucks and trains, by using access management services that allow exchanging information in real time. From the empirical findings of the studies conducted, six propositions are formulated and justified.

Keywords: Access management, information exchange, information services, turnaround times, road hauliers, rail operators, intermodal freight terminals, intermodal freight transport

List of appended papers

This thesis is based on research reported in five papers included in full after the cover paper.

Paper 1:

Jacobsson, S., Arnäs, P.O. and Stefansson, G. (2017), "Access management in intermodal freight transportation: An explorative study of information attributes, actors, resources and activities", *Research in Transportation Business & Management*, Vol. 23, pp. 106–124.

An earlier version of the paper was peer-reviewed and presented at the 14th World Conference on Transport Research held on 10–15 July 2016 in Shanghai, China.

Paper 2:

Jacobsson S., Arnäs, P.O. and Stefansson, G. (2018), "Differentiation of access management services at seaport terminals: Facilitating potential improvements for road hauliers", *Journal of Transport Geography*, Vol. 70, pp. 256–264.

An earlier version of the paper was presented at the 20th Logistics Research Network (LRN) Annual Conference held on 9–11 September 2015, in Derby, UK, and revised for peer-review and presented at the 28th Annual NOFOMA Conference, after being presented at the conference, held on 9–10 June 2016, in Turku, Finland.

Paper 3:

Jacobsson, S. (2019), "Potential improvements for access management in intermodal freight terminals: designing and testing a service for small road haulers", *World Review of Intermodal Transportation Research*, Vol. 8, No. 3, pp. 245–264.

Earlier versions of the paper were peer-reviewed and presented at the 29th Annual NOFOMA Conference held on 8–9 June 2017 in Lund, Sweden, and at the 21st LRN Annual Conference held on 7–9 September 2016, in Hull, UK. **The paper was awarded Best Doctoral Paper at the 29th NOFOMA Conference**.

Paper 4:

Jacobsson, S., Arnäs, P.O. and Stefansson, G. (in press), "Automatic information exchange between interoperable information systems: Potential improvement of access management in a seaport terminal", *Research in Transportation Business & Management.*

An earlier version of the paper was peer-reviewed and presented at the 15th World Conference on Transport Research held on 26–31 May 2019, in Mumbai, India.

Paper 5:

Jacobsson, S. (under review), "Managing terminal and transport processes with access management services", submitted to an international journal.

The researcher’s contribution to the appended papers

Paper	**First author**	**Second authors**	**Responsibilities of the authors**
1	Stefan Jacobsson	Per Olof Arnäs, Gunnar Stefansson	All three authors contributed equally to planning the paper and defining *access management*. The first author had sole responsibility for the literature review and data collection; he also conducted most of the data analysis and wrote most of the paper. The second and third authors analysed the data and wrote the paper to a lesser extent.
2	Stefan Jacobsson	Per Olof Arnäs, Gunnar Stefansson	All three authors contributed equally to planning the paper, strategising differentiation and determining the access performance indicators. The first author had sole responsibility for the literature review and data collection; he also primarily analysed the data and wrote the paper. The second and third authors analysed the data and wrote the paper to a lesser extent.
3	Stefan Jacobsson		The first author is the sole author of the paper.
4	Stefan Jacobsson	Per Olof Arnäs, Gunnar Stefansson	All three authors contributed equally to planning the paper and performing the cost–benefit analysis. The first author was responsible for most of the literature review, data collection and writing of the paper. The second and third authors contributed to analysing the data and writing the paper.
5	Stefan Jacobsson		The first author is the sole author of the paper.

Acknowledgements

Beginning in September 2014, my journey as a doctoral student has been among the most exciting, fun, educational, productive and inspiring experiences of my life, one that would have been impossible without the fantastic people who have accompanied me along the way.

I would first like to thank my primary supervisor, Gunnar Stefansson, and my deputy supervisor, Per Olof Arnäs, for helping me to see the bigger picture of my work. Given my background with technically driven research projects, in which details always need to be defined and explained according to various models, their support has been vital during my foray into the world of business research. Gunnar not only offered me valuable feedback on this thesis and the associated papers, as well as ways to improve them, but moreover nurtured me as a budding researcher. Perhaps more important, he gave me the perfect balance of the freedom and guidance that I needed, for which I will be forever thankful. To Per Olof, I want to express my profound gratitude for all of the support and pep talks towards taking the first steps on my journey. Without him, I would have most likely never entered the wonderful world of research, and I wish to thank him for the inspiring, endlessly stimulating conversations and his ability to visualise and present complex topics in an altogether approachable, understandable way.

I would also like to express my great appreciation of my examiner, Árni Halldórsson, whose academic skills, as both a teacher and reviewer, especially with methodologies, are truly impressive and whose valuable feedback tremendously improved this thesis. Additionally, I want to thank Hans-Eric Jacobsson at Consenso for his advice, his expertise in the industry and the opportunity to make my research a reality.

My sincere thanks also go to Vinnova and the Swedish Logistics and Transport Foundation (LTS) for funding my research projects, as well as to all of the organisations that participated in my studies, without whom my research would have been impossible. Special thanks are also due to John Wedel at LTS for supporting and believing in my research. I also wish to express my appreciation to the participants in my research projects for guiding me in the right direction, for engaging me in inspiring conversations, for sharing their expertise and for helping me with the empirical data collection.

A handful of fantastic, truly knowledgeable people at Chalmers University also merit recognition for their excellent support of me and my research. I want to thank Dan Andersson for so many interesting, fun conversations and for always helping me despite his busy schedule. My gratitude also goes to Mats Johansson and Patrik Jonsson, who always offered their expertise during the many times that I approached them for help with different problems, including for advice on this thesis and my article manuscripts. I would additionally like to thank Lars-Erik Gadde for explaining the industrial network approach to me and for such valuable feedback on Paper 5. Although I wish to thank all of my colleagues in the department, special thanks go to Jessica Wehner and Per Wide for their always interesting, valuable, good-natured discussions. I also thank my former roommate, Henrik Ringsberg for helping me with data collection, understanding theories and consistently enjoyable conversations.

A few people and organisations outside the university have also helped me out a great deal. Many thanks go to the SSPA team—Christian, Martin, Vendela and Sara—for the inspiring, valuable, rewarding conversations and for helping me to write the application for our next research project together. (I'm very much looking forward to working with you!) Special thanks also go to Henrik Sternberg at Iowa State University for helping me with data collection, for having such friendly, stimulating and for providing valuable feedback; even if the points made seemed overly critical at first, they proved to be invaluable to enhancing the quality of my research. I would also like to thank the ITS Postgraduate School for furnishing me with financial support to attend the world conference on transport research in Shanghai, China, and all senior researchers and doctoral students involved at the event, not only for their valuable comments on my research but also for their fascinating discussions.

Last, I would like to thank my family and friends for supporting me in different ways. I thank my friends Martin, Mattias and Håvard for encouraging me during much-needed phone calls from work. I also thank both of my brothers: Torbjörn for helping me with arranging my first conference presentation, for recommending good sources and for being a fun uncle to my children; and Hans-Eric for always believing in me and passing along his mind-set that nothing is impossible. I would additionally like to express my deepest appreciation to my parents for always supporting me and my family. Finally, my utmost gratitude goes to my wife, Stina, and our children, Ida and Joel, for standing by me through both fair and foul and for being the sunshine that gives perspective to my work and life. I hope that I can at last answer that undying question from my children: 'When are you going to be done with your book?' I love you so much!

Stefan Jacobsson

Gothenburg, May 2020

Table of contents

List of figures

List of tables

Acronyms

ABI/INFORM	Abstracted Business Information/Information Needs Database
API	Application programme interface
APICS	American Production and Inventory Control Society
CEO	Chief executive officer
DREAMIT	Digital Real-Time Access Management in Intermodal Transport
DSS	Decision support system
EDI	Electronic data interchange
ETA	Estimated time of arrival
FFA	Field force automation
FFM	Fleet and freight management
FMS	Fleet management system
GHG	Greenhouse gas
GPS	Global positioning system
GSCF	Global Supply Chain Forum
GSM	Global System for Mobile Communications
ICT	Information communication technology
ID	Identification
IT	Information technology
ITU	Intermodal transport unit
Paper 1	Research Paper 1
Paper 2	Research Paper 2
Paper 3	Research Paper 3
Paper 4	Research Paper 4
Paper 5	Research Paper 5
REACH	Real-time Access Management by Increased Information Exchange
RTS	Real-time systems
RQ	Research question
SC	Straddle carrier
SCM	Supply chain management
SCOR	Supply chain operations reference
Study 1	Empirical Study 1
Study 2	Empirical Study 2
Study 3	Empirical Study 3
SCE	Supply chain execution
TCP/IP	Transmission Control Protocol/Internet Protocol
TM	Transport management
TPS	Transaction-processing system
UNCTAD	United Nations Conference on Trade and Development
XML	Extensible mark-up language

1 Introduction

The topic of this thesis is access management for road hauliers and rail operators in intermodal freight terminals. This chapter elaborates upon that topic, identifies some problem areas therein and articulates the purpose, research questions, scope and delimitations of the thesis, before closing with an outline of the thesis's contents.

1.1 Background

Freight transport systems are essential to today's societies and economies (Rodrigue *et al.*, 2006; European Commission, 2011; Reis and Macário, 2019). For successful global logistics, freight transport has even been described as the glue that binds complex global supply chains together (Coyle *et al.*, 2015). However, in Europe, the annual 31.1% growth of all freight transport modes—road, rail, seaways, inland water ways, air and pipelines (European Commission, 2019)—continues to increase greenhouse gas (GHG) emissions (International Energy Agency, 2019) and congestion (European Commission, 2011). In response, a specific kind of freight transport—intermodal freight transport—can mitigate high GHG emissions and congestion, for it affords possibilities to switch load units from road transport to more sustainable modes such as rail, inland waterways and seaways (Lowe, 2005; Flodén, 2007). *Intermodal freight transport*, hereafter referred to as simply 'intermodal transport', is defined as 'the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes' (Economic Commission for Europe, 2001). In that definition, *loading units*, or 'intermodal transport units' (ITUs), refers to containers, semi-trailers and swap bodies (Woxenius, 1998; Economic Commission for Europe, 2001; Flodén, 2007).

Intermodal transport can be arranged within a network structure of nodes and links (Lumsden *et al.*, 2019). In such a network, a *link* represents the movements of ITUs and resources, whereas a *node* signals an interruption or stop in their movements. Along similar lines, the movements of ITUs and resources are enabled by intermodal transport processes, whereas their interruptions are enabled by intermodal freight terminal processes. In that sense, according to Davenport (1993), a *process* is 'a specific ordering of work activities across time and space, with a beginning, an end, and clearly identified inputs and outputs'. By extension, *activities* are actions owned and performed by actors that involve resources (Håkansson and Snehota, 1995). Whereas activities included in intermodal transport processes are road and rail haulage, pipeline transport and sea and air transport (Woxenius, 1998; Lowe, 2005), activities in intermodal freight terminal processes are the transhipment, sorting, stacking and coordination of ITUs (Crainic and Kim, 2007; Lumsden *et al.*, 2019). In particular, *transhipment* refers to the movement of an ITU from one transport mode to another (Bontekoning *et al.*, 2004).

In contrast to activities, *resources* are entities that are controlled and utilised by actors (Håkansson *et al.*, 2009). In transport, resources include vessels, trucks, trains and employees, and at terminals involved in intermodal transport in particular, resources include straddle carriers, cranes, employees and ITUs (Woxenius, 1998). Although an ITU can be regarded as a resource, the flows of ITUs are distinguished from the flows of resources, because the latter are created when ITUs are moved by using transport resources (Lumsden *et al.*, 2019). Other resources in intermodal transport are supportive information components such as information communication technologies (ICTs), information technology (IT) and information systems (Almotairi *et al.*, 2011). Well-functioning supportive information components are not only powerful but also necessary to enable flows of information among actors (Lumsden *et al.*, 2019). In that context, *actors* are organisations (Håkansson and Snehota, 1995) and according to Woxenius (2012) can include transport operators (e.g. road hauliers, rail operators and ship owners or shipping lines), intermodal freight terminal operators (e.g. seaport terminal operators, railroad terminal operators, inland waterway terminal operators and airport terminal operators) and transport coordinators (e.g. forwarders, third-party logistics providers and agents). Of those organisations, transport coordinators administrate and manage various logistics activities by exchanging information between transport operators and intermodal freight terminal operators (Stefansson, 2006).

The chief objectives of intermodal freight terminal operators, hereafter referred to as 'terminal operators', are to deliver seamless flow of ITUs through intermodal freight terminals (Marlow and Casaca, 2003) and to bridge gaps in differences between capacity, frequency and time in the various transport modes involved (Hultén, 1997). Bridging such gaps to achieve those chief objectives is the recognised purpose of terminals the world over (APM Terminals, 2020; DP World, 2020; PSA International, 2020). In general, terminal operators have to handle differences between large-scale transport operators, which ship large volumes at low frequencies, and small-scale transport operators, which ship small volumes at high frequencies. As a case in point, a seaport terminal operator needs to coordinate larger volumes—for instance, transported by mega vessels carrying more than 23,000 containers and arriving less than once per week (Ge *et al.*, 2019)—with smaller ones—for example, transported by trains with 120 containers arriving once or twice per week and trucks with three containers arriving once or twice per day (Steenken *et al.*, 2004). Due to the differences in volumes and frequencies, a terminal operator, with the help of transport coordinators, has to coordinate numerous small- and large-scale transport operators.

Given the massive flows of ITUs from large-scale transport operators that terminals have to process, terminal operators and small-scale transport operators face major challenges (Notteboom and Rodrigue, 2009; Meng *et al.*, 2017; Jeevan and Roso, 2019) in achieving seamless flows of ITUs through terminals (Marlow and Casaca, 2003). As a solution, terminal operators and small-scale transport operators (e.g. road hauliers and rail operators), along with their corresponding terminal and transport processes allowing the movement and handling of ITUs to, within and from terminals, are often arranged in intermodal transport systems by applying a systems approach (Gammelgaard, 1997; Lindskog, 2012). In this thesis, the system under study is part of an intermodal transport system encompassing transport coordinators and large-scale transport operators with corresponding transport processes and flows of resources and information. The studied part of the intermodal transport system can influence and be influenced by the system itself as well as be influenced by external factors, including laws and regulations, political and economic decisions (Woxenius, 1998), weather conditions, market initiatives and fluctuations in supply and demand (Liljestrand, 2016).

Figure 1 illustrates the system under study and how a terminal operator therein needs to coordinate numerous small-scale transport operators, which can influence and be influenced by transport coordinators and numerous large-scale transport operators with corresponding physical flows, information flows and transport processes beyond the studied system.

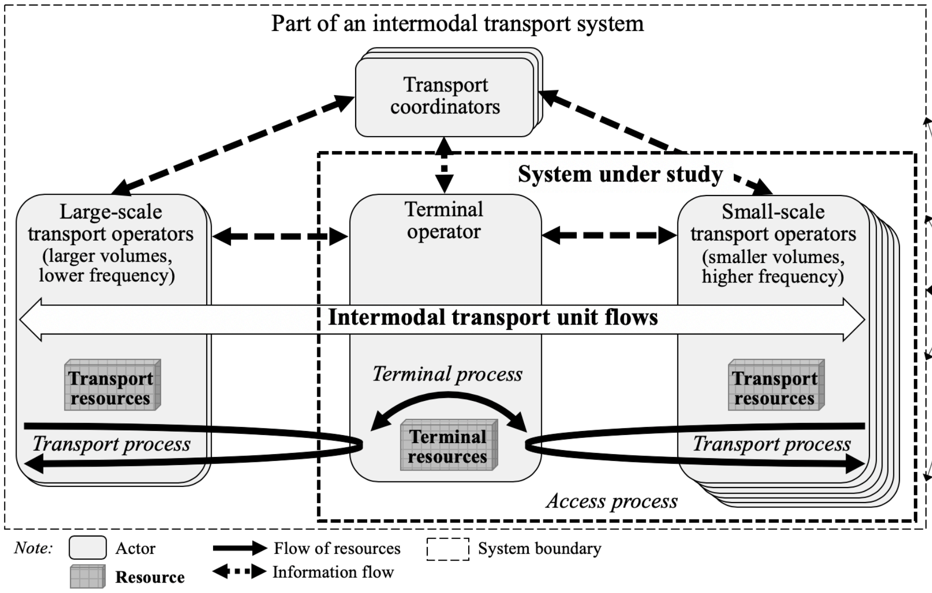

Figure 1. System under study

An important performance measurement for terminals in intermodal transport systems is *turnaround time* (Lubulwa *et al.*, 2011), defined as the length of time required for a truck or train that has entered the terminal to exit the terminal area (Islam *et al.*, 2013). The objective of the access process, as marked within the system shown in Figure 1, is to achieve seamless ITU flows to decrease turnaround times for trucks and trains. By way of the access process, small-scale transport operators can receive access to specific resources at terminals. To achieve an effective access process, transport resources (e.g. trucks and truck drivers) need to be managed in conjunction terminal resources (e.g. straddle carriers and straddle carrier drivers) in the right way at the right time. Such management, referred to as *access management* (see Section 1.3), relies upon information flows among terminal operators and small-scale transport operators (Holweg and Pil, 2008; Gharehgozli *et al.*, 2016). However, several problems can adversely affect the access process, its management and, in turn, turnaround times, as further described in the next sub-section.

1.2 Problem areas

Congestion at terminals is liable to adversely affect the access process (de Langen and Chouly, 2004; Namboothiri and Erera, 2008; Gharehgozli *et al.*, 2016) and, by extension, increase turnaround times (Dekker *et al.*, 2013; Phan and Kim, 2015; Ihebom *et al.*, 2019). On the one hand, congestion at terminals has intensified in recent years as a result of the rapid growth of freight transport that conveys massive flows of ITUs through terminals (Motono *et al.*, 2016). Handling such massive flows requires large numbers of trucks and trains (Notteboom and Rodrigue, 2009), as well as of actors and transport modes, all of which make the structure of intermodal transport networks rather complex (Marchet *et al.*, 2012). Such complexity increases as terminal operators have to be able to handle ever-increasing differences in the volumes, frequencies and quantities of large- and small-scale transport operators (Hultén, 1997) that stand to create bottlenecks at terminals (Crainic and Kim, 2007; Behrends, 2011; Islam *et al.*, 2013). Bottlenecks at terminals can also arise due to limited hours when gates are open (Maguire *et al.*, 2010) or when too few lanes or rail tracks are in service (Huynh and Walton, 2011).

On the other hand, congestion at terminals also arises as a result of inefficient terminal and transport processes (Maguire *et al.*, 2010). Inefficient terminal processes include all unnecessary movements and pointless container stacking at terminals (Steenken *et al.*, 2004), slow modal shifts (Woodburn, 2006) and inefficient loading and unloading activities (Sternberg *et al.*, 2013b). Such needless movements and container stacking typically occur when trucks arrive unannounced, which prevents terminals from planning for their arrival (Covic, 2017; Wasesa *et al.*, 2017). In fact, studies have shown that 85–90% of import containers and 60–84% of export containers are needlessly moved and stacked (Steenken *et al.*, 2004; Westbroek, 2012; Mutters, 2019). Meanwhile, inefficient transport processes include truck arrivals during peak hours (Maguire *et al.*, 2010), empty running, or when trucks have to return from terminals empty (McKinnon and Ge, 2006; Islam *et al.*, 2013), and unnecessary driver activities, including administrative tasks and idle waiting during loading and unloading (Sternberg, 2008; Sternberg *et al.*, 2014). Such administrative activities are undertaken to obtain information required to perform mandatory work tasks, or else to manually process paperwork, instead of using digital equipment such as electronic documents, sensors and cameras to complete those activities (Heilig and Voß, 2017). Added to those problems, the utilisation of resources may be poor due to bad resource planning and a lack of information (Sternberg *et al.*, 2013b).

On that topic, the relative lack of information exchange among actors in intermodal versus unimodal transport systems (Van der Horst and Langen, 2008; Islam *et al.*, 2013; Wiegmans *et al.*, 2018) stems from the relative complexity of intermodal systems (Caris *et al.*, 2013). At the same time, the lack of exchange often coincides with the scarcity of information that is adequate and timely (Sternberg, 2008), accurate and complete (Steenken *et al.*, 2004), in real time and of sufficiently high quality (SteadieSeifi *et al.*, 2014; Acciaro and Wilmsmeier, 2015). All of those information-related shortcomings derive from the dismal integration of supportive information components among actors involved and their poor exploitation of components already available (Almotairi *et al.*, 2011). Conditions explaining those setbacks include the incompatibility of the various actors' information systems (Caris *et al.*, 2013) or ICT components (Harris *et al.*, 2015), either of which, when combined with conservative mind-sets, make it difficult for the system's actors to adapt to new technologies (Marchet *et al.*, 2012;

Evangelista and Sweeney, 2014). Beyond that, the actors may distrust new systems (Cigolini *et al.*, 2016) or resist making changes and implementing costly new systems and applications simply because they lack the necessary human and economic resources (Stefansson and Lumsden, 2009; Marchet *et al.*, 2012; Evangelista and Sweeney, 2014; Harris *et al.*, 2015).

Thus, congestion at intermodal transport terminals is caused by several problems that can be grouped into three areas: complex network structure, inefficient processes and a low level of integration between supportive information components (Figure 2). All three problem areas negatively affect the access process and, as a consequence, increase turnaround times for trucks and trains.

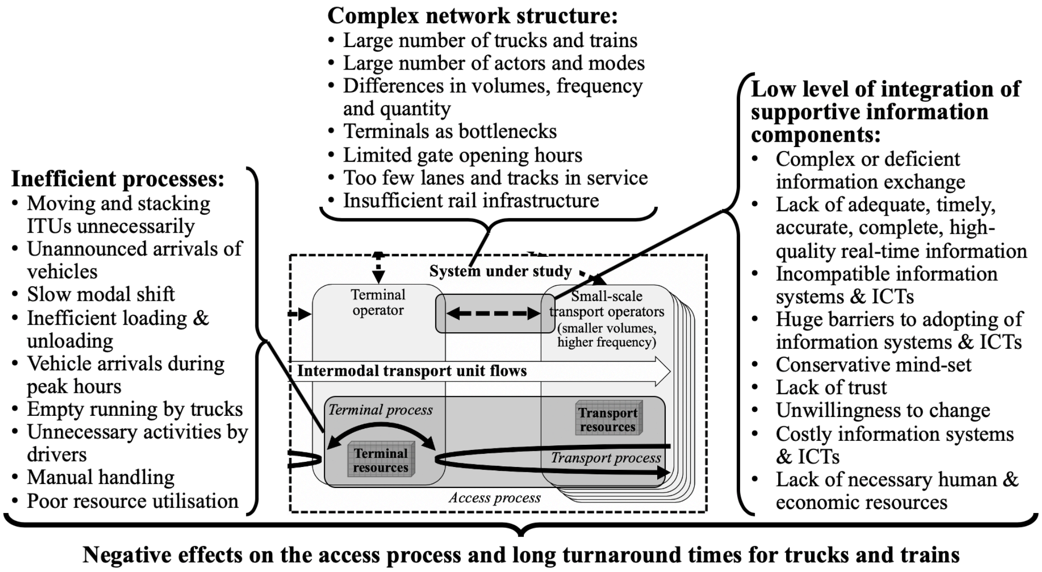

Figure 2. Problem areas in the system under study

For example, a truck's turnaround time can range from one and six hours, depending upon the wait time (Morais and Lord, 2006; Giuliano and O'Brien, 2007; Ramírez-Nafarrate *et al.*, 2017). Without any wait time, the average turnaround time is 20–30 minutes (Huynh, 2009; Lubulwa *et al.*, 2011), which shows how significantly wait time contributes to increased turnaround time. In turn, longer wait times increase the idling of trucks (Do *et al.*, 2016; Phan and Kim, 2016), which generates more GHG emissions (International Energy Agency, 2019), elevates the stress and reduces the quality of work conditions for terminal and intermodal transport employees alike (Montreuil, 2011), raises salary costs for time wasted (Sanchez Rodrigues *et al.*, 2008; Sternberg *et al.*, 2014) and raises fuel costs with each idling truck and empty run made.

1.3 Access management

To address the three problems areas that adversely affect the access process, its management and turnaround times for trucks and trains, a better understanding of access management is needed.

Access management refers to managing the process by which actors access resources at terminals.

In that definition, *access* is granted by the actor controlling specific resources (e.g. terminal operators) and is received by the actor that requires those resources (e.g. road hauliers and rail operators) (Wong and Karia, 2010). The specific resources include specific ITUs, loading bays, and entry lanes, at terminals. *Management* involves planning, monitoring, controlling and coordinating such access, typically in collaboration with other actors in the intermodal transport system (Council of Supply Chain Management Professionals, 2019). To date, studies conducted by, for example, Namboothiri and Erera (2008); Marchet *et al.* (2009); Marchet *et al.* (2012) have focused on functions of access control at terminals and ports, including the automation of gate entry and exit, as well as boarding operations by means of automated ITUs and vehicle identification. In general, the purposes of those functions are enhanced security at terminals, safer work environments for human resources, better commercial relations or improved efficiency (Andritsos, 2013), the last of which is the focus of this thesis. However, because such functions control the access of trucks and trains at terminals only (Van der Horst and Langen, 2008), they do not concern the management of access to resources at terminals.

To manage the access process (Namboothiri and Erera, 2008; Wong and Karia, 2010), information exchange among actors in the intermodal transport system is crucial (Buijs and Wortmann, 2014; Bisogno *et al.*, 2015), especially the exchange of relevant, timely information (Auramo *et al.*, 2005; Kaipia, 2009; Bhakoo *et al.*, 2015; Dubois *et al.*, 2019). The literature highlights five information services that can be mobilised to enable the exchange of such information:

- Information access services (Heilig and Voß, 2017);
- Automated gate services (Dekker *et al.*, 2013);
- Pre-notification and appointment services (Chen *et al.*, 2013; Phan and Kim, 2015);
- Real-time information exchange platform services (Kaipia, 2009; Carlan *et al.*, 2016; Dubois *et al.*, 2019); and
- Dedicated access services (Boile and Sdoukopoulos, 2014).

All five of those services depend upon supportive information components, including information systems, ICT and IT (Almotairi *et al.*, 2011), and have a primary objective of decreasing turnaround times for trucks and trains. Examples of such services successfully implemented to date are pre-notification and appointment services, which have decreased turnaround times at terminals by 30% (Phan and Kim, 2015), and real-time information exchange platform services, which can decrease turnaround times by 39% (Carlan *et al.*, 2016). A simulation model developed by Dekker *et al.* (2013) shows that turnaround times can be decreased by up to a staggering 83% once automated gate services are added. Given their potential to increase turnaround, information services are of particular interest to researchers and practitioners (Perego *et al.*, 2011). For example, two research initiatives—smartPORT at the Port of Hamburg, Germany (Hamburg Port Authority, 2017) and SmartPort in Rotterdam, the Netherlands (Smart port community, 2017)—have demonstrated how using information services can at once promote sustainable economic growth and minimise environmental impacts.

1.4 Purpose and research questions

At the time of writing this thesis, little research has provided a holistic approach for access management that focuses on how small-scale transport operators (i.e. road hauliers and rail operators) can access specific resources (e.g. specific ITUs, loading bays, and/or entry lanes) at terminals at certain times of day in order to decrease turnaround times for trucks and trains.

The purpose of this thesis is to increase the understanding of how access management for road hauliers and rail operators in intermodal freight terminals can contribute to decreasing turnaround times for trucks and trains.

To that purpose, the problem-solving path articulated by Booth *et al.* (2008) has been employed to guide a research process for the thesis, beginning with the identification of a practical problem, followed by formulating any number of research questions (RQ) that define a research problem, and ending by addressing the RQs and, in that way, offering answers to the practical problem. From the three problem areas identified in Section 1.2, three RQs were identified and formulated, as presented in what follows.

The network structure of the intermodal transport system studied for this thesis involves large numbers of actors (i.e. terminal operators and small-scale transport operators) and transport modes. As mentioned, intermodal transport remains extremely complex, with little known about what actors are involved and how they exchange information, if at all, even though several research teams (Marchet *et al.*, 2009; Marchet *et al.*, 2012; Bisogno *et al.*, 2015; Ramírez-Nafarrate *et al.*, 2017; van der Horst and de Langen, 2017) and practitioners (DHL, 2019; DB Schenker, 2020; Kuehne+Nagel, 2020) have focused on reducing that complexity by improving information exchange. At the same time, research on inefficient terminal and transport processes remains rare, especially regarding the movement of ITUs to, within and from terminals and the activities and resources involved in those endeavours (Elbert *et al.*, 2017). Although practitioners have applied different information systems to improve terminal processes (Navis, 2020a), road processes (K2, 2019) and rail processes (Hogia, 2020), all of those processes continue to be inefficient. Thus, a clearer understanding of inefficient terminal and transport processes involved in accessing resources at terminals is required, as are insights into the complexity of the network structure in terms of the actors involved and their exchanges of information when resources at terminals need to be accessed.

To those ends, and addressing the terminal and transport processes and actors involved therein, RQ1 was formulated as:

RQ1: What processes and actors are involved in accessing resources at intermodal freight terminals?

As stated in Section 1.2, the poor integration of supportive information components at terminals stems from incompatible information systems and ICT applications, which hinder the exchange of information among the actors involved. Several studies have stressed the importance of information exchange among such actors (Baron and Mathieu, 2013; Islam *et al.*, 2013; Carlan *et al.*, 2016; Gharehgozli *et al.*, 2016), the need for reliable information to access resources at terminals (Natvig, 2009) and that good information exchange between actors is key to improving efficiency at terminals (Sternberg *et al.*, 2012; Bisogno *et al.*, 2015). From another perspective, practitioners have stressed the importance of supportive information components and services to enabling the seamless exchange of information (IBM, 2020; Mymo Terminal, 2020; Navis, 2020b). However, few research teams and practitioners have investigated ways of improving information exchange for terminals (Stefansson and Russell, 2008; Almotairi *et al.*, 2011; Elbert *et al.*, 2017) or the exchange of high-quality information in real time (SteadieSeifi *et al.*, 2014; Acciaro and Wilmsmeier, 2015), which is necessary to facilitate effective access to resources at terminals. Although information exchange can be enabled by the five information services previously mentioned, researchers to date have mostly investigated how specific information services are designed to decrease turnaround for trucks or trains at terminals, thereby overlooking conditions in which more services have been applied. For example, studies examining the minimisation of turnaround times based on one type of information service (e.g. Zhao and Goodchild, 2013; Huynh *et al.*, 2016; Phan and Kim, 2016) have ignored the various ways in which different information services can contribute to decreasing turnaround times. Consequently, more in-depth examinations are needed on what supportive information components and services are required to enable effective access to resources at terminals. In that sense, *effective access*, with reference to Drucker's (1986) definition of *effectiveness* as 'doing the right things', means access to the right resources (e.g. specific ITUs, loading bays and entry lanes) at terminals at the right time. Thus, addressing required supportive information components (i.e. information systems, ICT applications and information) and required information services, RQ2 was formulated as:

RQ2: What supportive information components and services are required to enable effective access to resources at intermodal freight terminals?

The complex structure of intermodal transport networks, the poor integration of supportive information components and inefficient terminal and transport processes increase turnaround times for trucks and trains (Huynh, 2009; Lubulwa *et al.*, 2011; Ramírez-Nafarrate *et al.*, 2017). As mentioned, to address those problems, a better understanding of access management and of ways to improve both its effectiveness and information exchange among the actors involved is needed. In this thesis, *effective access management* means the automatic exchange of the right information at the right time (Sternberg *et al.*, 2012; Kurapati *et al.*,

2015) towards ensuring that the actors involved can effectively manage the terminal and transport processes in question (Van der Horst and Langen, 2008; Neagoe *et al.*, 2017). As a result, the actors should be able to grant or receive access to the right resources at terminals at the right time (Wong and Karia, 2010; Yang, 2016) as a means to decrease turnaround times for trucks and trains (Goodchild *et al.*, 2011; Mathias *et al.*, 2018). Therefore, the potential effects of effective access management need to be explored in three aspects: *effective automatic information exchange* (i.e. how the right information can be automatically exchanged at the right time), the *effective management of terminal and transport processes* (i.e. how actors can manage terminal and transport processes involved in effectively accessing resources at terminals) and *effective access* (i.e. how access to the right resources at terminals at the right time is granted or received). Taken together, those potential effects can contribute to decreasing turnaround times for trucks and trains at terminals, hence RQ3:

RQ3: How can effective access to resources at intermodal freight terminals be managed?

Altogether, by addressing the three RQs, the thesis will achieve its stated purpose by illuminating how access management for road hauliers and rail operators at terminals can help to decrease turnaround times for trucks and trains.

1.5 Delimitations

Involving phenomenon-driven instead of theory-driven research, this thesis centres on the phenomenon of access management for road hauliers and rail operators at terminals. As earlier defined and briefly described, *access management* refers to the planning, monitoring, controlling and coordination of the access process of actors involved (road hauliers, rail operators and terminal operators) in intermodal transport networks as they access specific resources (e.g. ITUs, loading bays and entry lanes) at terminals at certain times of day. Managing the access process relies on information exchange that can be enabled by implementing the five identified information services, all of which are based on various supportive information components, including information systems, ICTs and ITs.

Of the four types of terminals—seaport, railroad terminals, inland waterway terminals and airports (Lowe, 2005; Roso *et al.*, 2009)—seaport and railroad terminals are examined in this thesis, not only due to their crucial roles in logistics and supply chains (McCalla, 1999; Lam and Su, 2015) but also because ITU flows are processed at both types (Higgins *et al.*, 2012). Seaport terminals offer transhipment between maritime and land-based transport (e.g. with trains or trucks; Lumsden *et al.*, 2019), whereas railroad terminals provide transhipment between smaller modes of transport than road and in larger volumes than in rail and inland waterways (Boysen *et al.*, 2012). Because the thesis focuses on two types of terminals, two set-ups of the system under study (see Section 1.1) are included herein: a seaport terminal set-up and a railroad terminal set-up. Whereas the seaport terminal set-up includes seaport terminal operators, road hauliers and rail operators, the railroad terminal set-up includes railroad terminal operators and road hauliers. By further contrast, the seaport terminal set-up receives more attention in this work than the railroad terminal set-up, just as road haulage receives more focus than rail haulage, because they experience the identified problem areas to a greater degree (see Section 1.2).

1.6 Outline of the thesis

This chapter has described the background to the thesis, the problems addressed, the concept of access management, the purpose of the research, the three RQs and the scope and delimitations of the research. Next, in presenting the frame of reference for the thesis, Chapter 2 addresses literature relevant to the topic and explores the current body of knowledge about intermodal transport in the management of supply chains and logistics, as well as about access management, from three perspectives: network structure, management components and information services. Chapter 3 describes the methodology of the research in terms of its approach, design, the various studies involved and its validity, after which Chapter 4 provides a summary of each of the five appended papers. After Chapter 5 presents the findings from the five papers, which serve to answer the three RQs, Chapter 6 provides a discussion that ultimately results in six propositions based on the findings in the five papers. In closing, Chapter 7 describes some of the conclusions and contributions of the research, followed by a brief outlook for further research on the topic.

2 Frame of reference

This chapter presents the frame of reference that served as a foundation for the research conducted for the thesis. Developed in light of a review of relevant literature, the frame of reference was designed to gain additional insights into access management.

2.1 Intermodal transport in the context of supply chain management and logistics

According to the Council of Supply Chain Management Professionals (2019), *supply chain management* (SCM) encompasses 'the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities'. In literature addressing SCM, two well-known supply chain frameworks have been proposed (Naslund and Williamson, 2010): the supply chain operations reference (SCOR) framework (APICS, 2019) and the Global Supply Chain Forum's (GSCF) framework (Cooper *et al.*, 1997). On the one hand, the SCOR framework enables different levels of detail when describing, measuring and evaluating supply chains while using five business processes: planning, sourcing, making, delivering and returning. In capturing only those five business processes, the SCOR framework overlooks other processes, including the implementation of IT, research and technology development, product development and, among others, sales and marketing (Jonsson, 2008).

On the other hand, the GSCF framework comprises three closely inter-related elements: the supply chain network structure, SCM components and supply chain business processes (Figure 3).

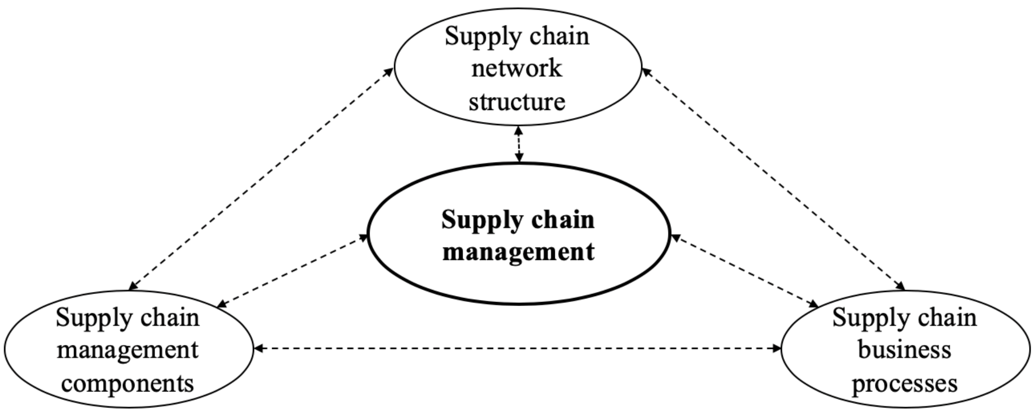

Figure 3. The three closely inter-related elements in the GSCF framework (Cooper et al., 1997)

The first element, the *supply chain network structure*, encompasses the key actors in the supply chain and the business processes that link them. The second, *SCM components*, determines how each linked business process is managed for successful SCM. The third, *supply chain business processes*, represents a structured set of activities designed to facilitate flows of information, knowledge, money, resources and materials. Altogether, the three closely inter-related elements capture how supply chain networks are structured and managed (Cooper *et al.*, 1997; Lambert *et al.*, 1998a; Lambert and Cooper, 2000).

Several published works discuss the relationship between SCM and logistics management (Cooper *et al.*, 1997; Lambert *et al.*, 1998a; Mentzer *et al.*, 2001; Larson and Halldórsson, 2004). According to the Council of Supply Chain Management Professionals (2019), *logistics management* is the 'part of SCM that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements'. That definition maintains that logistics management is part of SCM, even though prior research has suggested that their relationship is different. For example, Larson and Halldórsson (2004) have argued that they are linked in four different ways, whereas Lummus and Vokurka (1999) have posited that SCM is not logistics management. Although definitions of the term differ, this thesis considers logistics management to be part of SCM (Cooper *et al.*, 1997; Lambert *et al.*, 1998a; Jonsson, 2008; Christopher, 2016; Council of Supply Chain Management Professionals, 2019) and to encompass activities emerging from inventory management, physical distribution and freight transport (Aastrup and Halldórsson, 2008).

Freight transport, an important part of both logistics and SCM (Hesse and Rodrigue, 2004; Coyle *et al.*, 2015), can be described as having three layers—material flow, transport operation and transport infrastructure (Figure 4)—each of which constitutes a network with nodes and links (Wandel *et al.*, 1992).

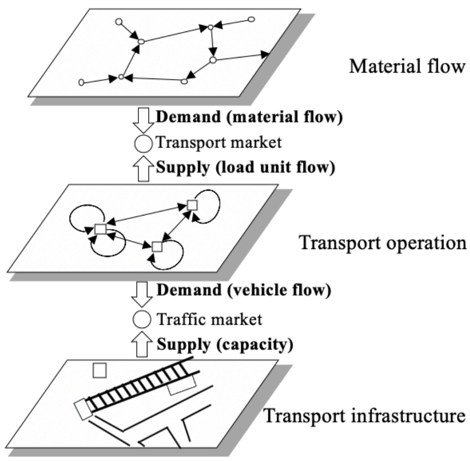

Figure 4. A three-layer model of freight transport (Wandel et al., 1992)

The first layer, *material flow*, describes the flow of materials as a process of links and nodes, whereas the second, *transport operation*, models transport activities and corresponding activities generated by transport service companies. One result of transport activities is the flow of ITUs and vehicles among nodes. The third layer, *transport infrastructure*, refers to the physical infrastructure and its management. Taken together, the layers of the transport system interact in terms of demand and supply. For example, vehicle flow creates demand that is met with supplies conveyed via transport infrastructure in terms of capacity, which in turn creates a traffic market. Of all three layers, transport operation receives primary focus in this thesis, for it concerns the flow of load units—that is, ITU flows—but not the flows of materials within the ITUs. Nevertheless, the transport infrastructure network also receives attention, because terminals are important pieces of that infrastructure at which access to resources (e.g. specific ITUs, loading bays and entry lanes) can be granted or received.

The flows of freight transport shown in Figure 4 can be divided into four types (Lumsden *et al.*, 2019): material, resource, information and money (Figure 5).

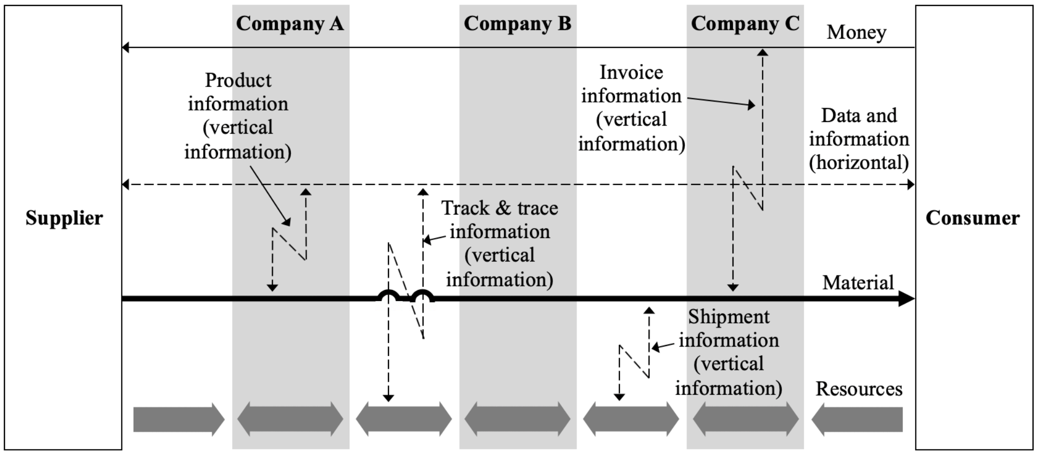

Figure 5. Flows in logistics (Lumsden et al., 2019)

For one, *material flow* is created by moving goods, which in turn creates a resource flow, because goods have to be connected to ITUs. For another, *resource flow* is always bidirectional, because resources are not consumed within the system. By contrast, *information flow* occurs both horizontally and vertically; after all, horizontal information flow creates the need for both its vertical counterpart and information about goods, the status of resources and their physical locations. Last, *monetary flow* is controlled among the seller, buyer and conveyor of goods with the help of information from the other flows.

In intermodal freight transport, given the possibilities of switching freight from road to more sustainable modes of transport (e.g. rail, seaways and inland waterways), achieving the chief objectives depends upon environmental and economic variables (Lowe, 2005; Flodén, 2007). To succeed, intermodal freight transport depends upon four major aspects (Lumsden *et al.*, 2019): the availability of technology for switching freight among modes, the flexibility of the transfer of equipment (e.g. straddle carriers), the handling of ITUs and the adaption of transport units (e.g. railway wagons) to handle those ITUs. For example, because ITUs increase flexibility and preclude manual loading and unloading during transhipments, they reduce the money and time spent on the activities as well as lower the risk of damage to goods (Woxenius, 1998).

2.2 Access management

To capture the essence of access management, this thesis has adopted the logic of the GSCF framework (Cooper *et al.*, 1997), because, unlike the SCOR framework (APICS, 2019), it does not exclude IT, which is an important tool for addressing and resolving the identified problems related to the poor integration of supportive information components at terminals. The GSCF framework attempts to capture the essence of SCM by viewing it in terms of three closely inter-related elements

(Cooper *et al.*, 1997): network structure, management components and business processes. Concerning its elements, the logic of the GSCF framework can be applied at lower levels of the system including logistics systems, intermodal transport systems and the system under study, all of which are part of supply chain systems, as previously discussed. Thus, with reference to the GSCF framework, the essence of access management can be captured by adapting the logic of the framework's three elements to accommodate the system under study. In the sub-sections that follow, access management is described in terms of those three elements.

2.2.1 Network structure

The supply chain network, according to Cooper *et al.* (1997), has three components: the primary actors involved, the network structure and the actors' abilities to manage their business processes. In this thesis, the primary actors are road hauliers, rail operators and terminal operators, all of which are described first in what follows. The structural dimension of the system under study is described and illustrated in Section 1.1, whereas the actors' abilities to manage their business processes are described and analysed in terms of the industrial network approach in Section 3.3.

Road hauliers

In intermodal transport, road haulage, comprising pre- and post-haulage (Woxenius and Bärthel, 2008), is the activity in which ITUs are transported on roads (Woxenius, 1998). The major challenges of road haulage are achieving high resource utilisation at a low cost and delivering a quality of transport demanded by customers (Behrends *et al.*, 2011). The needs of customers can often be fulfilled by road haulage owing to its small-scale quantities, adaptability, flexibility, safety, reliability and services (Lumsden *et al.*, 2019). Other activities involved in road haulage are handling ITUs, handling documents, retrieving information and, in the case of bottlenecks at terminals, waiting during the loading or unloading of ITUs onto or from trucks (Sternberg *et al.*, 2014). Those activities are performed mostly with resources such as transport planners, truck drivers and trucks. Regarding the last of those resources, trucks in intermodal transport come in four types (Lumsden *et al.*, 2019): unit load carriers (i.e. with a load carrier affixed to the truck), semi-trailers (i.e. with a load carrier that can be disconnected from the truck), swap body trucks (i.e. with detachable platforms and foldable support legs) and side loader trucks (i.e. with lift equipment for ITUs).

Rail operators

Compared to road transport, rail transport is preferable for longer distances (de Langen *et al.*, 2017) and is viewed as more sustainable transport because it emits fewer GHG emissions (Heinold and Meisel, 2018) and exerts low friction on rails (Lumsden *et al.*, 2019). The roles of railway companies entail operating terminals, supplying rail wagons and selling rail haulage between terminals (Woxenius, 1998). Rail haulage is dictated by the organisational structure of the entire intermodal transport network, such that freight trains may need to be driven at night, because passenger trains are prioritised during the day, meaning that most of the freight trains arrive in the morning and leave in the evening (Ballis and Golias, 2002). In conjunction with terminals, rail haulage involves not only the shunting of locomotives and rail wagons, because terminals can handle trains no more than 750 metres long (Lumsden *et al.*, 2019), but also marshalling, in which ITUs are transhipped between trains (Ricci and Black, 2005). Those activities can be performed by using various resources (Lumsden *et al.*, 2019); *CarConTrain* are trucks and wagons connected with beams to tranship ITUs, *rolling highways* allow trucks to drive up onto the wagons by using a ramp, and *bimodal systems* involve semi-trailers that are loaded or unloaded into the wagons.

Intermodal freight terminals

At intermodal freight terminals, owners and operators play major roles (Wiegmans *et al.*, 1999). Terminal owners, which can be private or public entities, if not both, chiefly serve to facilitate central terminal services, including the provision of terminals and office space (Wiegmans *et al.*, 1999). By contrast, terminal operators chiefly provide terminal services—transhipment, sorting, stacking and coordinating ITUs (Bontekoning *et al.*, 2004; Crainic and Kim, 2007; Lumsden *et al.*, 2019)—that customers request and at the best possible prices (Wiegmans *et al.*, 1999). In those services, ITUs are transhipped, or moved, from one transport mode to another, after which they are sorted and stacked due to different criteria and, in turn, coordinated to optimise their flows in ways that accommodate differences in the variations, frequencies and capacities of arriving vessels, trains and trucks. Performing those services requires various resources (Lumsden *et al.*, 2019). Moving ITUs at terminals, for instance, requires using straddle carriers, terminal tractors and wagons. Handling ITUs to and from trucks, by contrast, requires using sidelifters and counter-balanced trucks, whereas handling them to and from trains requires gantry cranes.

2.2.2 Management components

Cooper *et al.* (1997); Lambert *et al.* (1998a); Lambert and Cooper (2000) have identified nine SCM components: planning and control methods, workflow activity structure, organisation structure, communication and information flow structure, product flow structure, culture and attitude, power and leadership structure, risk and reward structure and management methods. The major goals of those components are managing and structuring business processes within the supply chain (Cooper *et al.*, 1997; Lambert *et al.*, 1998a; Lambert and Cooper, 2000). Of those nine components, the communication and information flow structure needs to be integrated first (Cooper *et al.*, 1997; Wolf and Seuring, 2010; Mulholland *et al.*, 2018). That structure includes the same components as the supportive information components mentioned in Chapter 1—information systems, ICT applications and information exchange—as described below.

Information systems

Information systems are composed of people and computers that produce, collect, process, filter, distribute and interpret information (Kroenke *et al.*, 2013). In freight transport and other contexts, they also typically include ICT applications that enable and improve collaboration among the actors involved (Dürr and Giannopoulos, 2003). Information systems consist of three fundamental sub-systems: the physical sub-system, the decision-making sub-system and the information sub-system (Romero and Vernadat, 2016). Overall, the information sub-system stores, transmits and communicates information to the decision-making sub-system, which in turn controls the physical sub-system (Anglani *et al.*, 2002). In greater detail, the physical sub-system consists of physical components such as actors, resources and both material and physical flows (Romero and Vernadat, 2016). The decision-making sub-system, by contrast, is composed of decision support systems that supply information to decision makers, whereas the information sub-system is composed of real-time systems and transaction-processing systems (Wortmann *et al.*, 2013). Of those types of systems, real-time systems monitor physical variables (e.g. text, numbers, audio and video) via sensors and update transaction-processing systems with those variables (Buijs and Wortmann, 2014). For their part, transaction-processing systems can communicate with other transaction-processing systems at other organisations via electronic data interchange (EDI) or extensible mark-up language (XML; Buijs and Wortmann, 2014).

ICT applications

Focusing on intermodal transport, Marchet *et al.* (2009); Marchet *et al.* (2012) have identified four ICT-based applications—transport management applications, supply chain execution applications, field force automation applications and, last, fleet and freight management applications—the last three applications can all be processed in real time. First, transport management applications are decision support tools for transport planning, optimisation and execution. They can afford functions such as terminal operation management and monitoring as well as accounting and finance functions. Second, supply chain execution applications facilitate information exchange and real-time management used in order tracking and processing, for instance. Third, field force automation applications comprise workforce management systems and mobile technology tools (e.g. Wi-Fi devices) that support in-field activities. Last, fleet and freight management applications allow access control, the monitoring of parameters (e.g. travel times, service times, delivery points visited and load temperatures) and vehicle tracking and tracing.

Information exchange

Four facets define information exchange among actors (Mohr and Nevin, 1990): frequency, direction, modality and content. First, *frequency* describes how often information needs to be exchanged among actors in order to be used effectively. In intermodal transport, for example, the frequency of flows of information may be altered when hauliers plan new routes to pick up or deliver ITUs to terminals. Second, *direction* describes how information is exchanged: either bidirectionally (i.e. in two directions) or unidirectionally (i.e. in one direction). Direction also characterises whether the information flow is inter-organisational or intra-organisational. Third, *modality* refers to the medium used for information exchange: either via analogue devices (e.g. over the telephone) or digitally (e.g. video chat, email and social media). Fourth and last, *content* refers to the messages transmitted, which in this thesis are structured according to the object-oriented paradigm (Booch, 1991) and presented as information attributes.

2.2.3 Business processes

Processes are structured sets of activities designed to facilitate flows of information, knowledge, money, resources and materials (Cooper *et al.*, 1997; Lambert *et al.*, 1998a; Lambert and Cooper, 2000; Lambert and Enz, 2017). This thesis, as previously stated, focuses exclusively on flows of information, resources and ITUs, all of which can be managed by using different information services that enable information exchange. The following paragraphs detail the chief functions and characteristics of those services.

For one, *information access services* include services constructed via a web interface or browser (Baumgrass *et al.*, 2015) and can promote information sharing only from a terminal to road hauliers or rail operators. Terminals can provide information to road hauliers via webcams (Huynh *et al.*, 2011), information systems or webpages (Heilig and Voß, 2017). For example, the cloud-based smartPORT logistics project in Hamburg, Germany, provides information about traffic, accidents and congestion (Heilig and Voß, 2014).

Another set of services is *automated gate services*, which use automated gate systems to minimise unnecessary stops for trucks at terminals by affording automated ITU inspections (Dekker *et al.*, 2013). Such systems can allow information sharing via port community systems (Heilig and Voß, 2017), without which some terminals have introduced self-service stations located externally. By using those stations, truck drivers can notify terminals of their arrivals, which can expedite processing at gates (Heilig and Voß, 2017). However, regarding processing at the terminal gates, truck arrivals cannot be managed to off-peak hours with automated gate services.

Next, *pre-notification and appointment services* involve using timeslot allocation systems (Giuliano and O'Brien, 2007), including truck appointment systems (Chen *et al.*, 2013; Phan and Kim, 2015), vehicle booking systems (Islam *et al.*, 2013; Islam and Olsen, 2014) and truck scheduling (Hall, 2001). Such services enable trucks to notify terminals of delays along their routes and their expected arrival times at terminals (Wasesa *et al.*, 2017). With such information, terminals can begin readying access for road hauliers in advance. Using pre-notification and appointment services enables terminals to equally distribute truck traffic timewise by allowing them to manage trucks that arrive during off-peak hours (Giuliano and O'Brien, 2008).

In addition, *real-time information exchange platform services* combine decision support systems, real-time systems and transaction-processing systems (Buijs and Wortmann, 2014). As an example, port community systems enable real-time information exchange among actors (Heilig and Voß, 2017), who can thereby improve the visibility of their processes and conduct accurate, effective transactions (Carlan *et al.*, 2016; Huynh *et al.*, 2016). By exchanging real-time congestion information, for instance, truck arrivals can be processed during off-peak hours, which minimises congestion at terminals (Sharif *et al.*, 2011).

Last, based on information systems involving pre-notification and appointment services and real-time information exchange platform services coupled with corresponding characteristics of information flows, *dedicated access services* allow road hauliers with appointments at terminals to access priority lanes (e.g. green lanes) or timeslots based on price, urgency or liability (Zhao and Goodchild, 2013). By exchanging the necessary information, terminals can easily handle truck traffic and, in turn, distribute arrivals to off-peak hours (Boile and Sdoukopoulos, 2014; Heilig and Voß, 2017).

2.3 Synthesis: Conceptualising access management for road hauliers and rail operators in intermodal freight terminals

The three closely inter-related elements (i.e. the supply chain network structure, SCM components and supply chain business processes) can be adapted to suit the system under study and capture the essence of access management. In that case, they have been renamed *access network structure*, *access management components* and *access management services*. Access management services include information services (see Section 2.2.3), whereas the access network structure includes terminal and transport processes, the chief actors involved (i.e. road hauliers, rail operators and terminal operators) and how they exchange information. Last, access management components, including communication and information flow structure, may be affected by planning and control (Zhou and Benton Jr, 2007) and attitudes that influence how employees adopt and react to information (Mondragon *et al.*, 2017).

Those three elements of access help to conceptualise the phenomenon of access management for road hauliers and rail operators at terminals. In particular, adapting and integrating the GSCF framework can clarify how the access network is structured, what access management components are needed to structure and manage information exchange in access management services and how those services can contribute to decreasing turnaround times for trucks and trains at terminals. The overall analytical framework with the three elements of access and the three RQs is depicted in Figure 6.

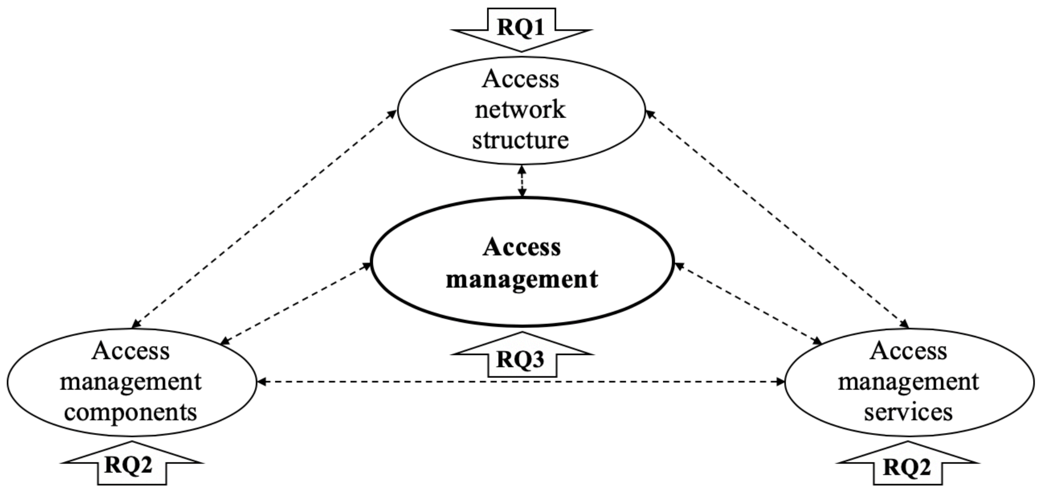

Figure 6. Overall analytical framework with the three elements of access and three RQs

The goal of the three elements of access is to interconnect with each another in order to achieve effective access to specific resources. For example, the access network structure, with its various processes and actors involved, constitutes how and what access management services can be provided and used. The services, by contrast, enable information exchange that is structured and managed by the components of access management.

3 Methodology

This chapter presents the research methodology, by providing an overview of the data needed and appropriate methods, by justifying the research process, approach and design, and by explaining the research's validity.

3.1 Overview of data needed and appropriate methods

In general, the data needed to answer the three RQs and the appropriate research methods for collecting and processing such data depend upon the types and formulations of the RQs as well as the current body of knowledge on the topic (Ellram, 1996; Maxwell, 2013; Yin, 2013; Flick, 2014). Although the relationships between the RQs and the body of knowledge is depicted in the overall analytical framework in Figure 6, Table 1 further describes those relationships and presents which data and appropriate methods were needed.

Table 1. Overview of research questions, data needed and research methods

Element of access	**RQ**	**Data needed**	**Research methods**
Access network structure	RQ1: Terminal and transport processes and actors involved	Perceptions of terminal and transport processes Overview of actors involved and their information exchange	Literature review and participant observations Literature review and semi-structured interviews
Access management components and services	RQ2: Required supportive information components and services	Identification of required information systems and ICT applications Identifications of required and most relevant information attributes Identification of required access management services	Literature review and focus groups Literature review and focus groups Literature review and focus groups
Access management	RQ3: Effective access management	Explanation of how automatic information exchange can be effectively managed Explanation of how the terminal and transport processes involved can be effectively managed Explanation of how effective access can be managed	Literature review and focus groups Semi-structured interviews and focus groups Time measurements, focus groups and semi-structured interviews

The choices of research methods are described and explained in Section 3.4.

3.2 Research process

Commencing in September 2014, the research for this thesis was conducted in two research projects: the REACH project and the DREAMIT project, hereafter respectively referred to as 'REACH' and 'DREAMIT' (see Appendix B). In both projects, access granted to the industrial project partners afforded valuable opportunities for collecting data in real-life situations. In terms of consequentiality, the results gathered from REACH informed the findings from

DREAMIT. In REACH, the research focused exclusively on road hauliers and ways of improving their access management. However, once it was recognised during the project that improving access management for road hauliers would be impossible without considering the needs of rail operators and terminal operators as well, developing a more inclusive systems perspective became necessary. Additionally, REACH initially focused solely on a railroad terminal, as the project proceeded, attention shifted to a seaport terminal as the project partners, who ship ITUs to both terminals, increasingly stressed several problems with access at the seaport terminal. Furthermore, once an access management service was tested that revealed some problems with manually handling, more attention was paid to how such information can be automatically exchanged between the information systems of the actors involved in order to reduce those problems. Thus, DREAMIT not only adopted a broader systems perspective but also focused on automatic information exchange between their interoperable information systems to improve the access management for actors involved and to reduce problems with manually handling of the tested access management service.

3.3 Research approaches

Because different approaches can be taken to provide a comprehensive view of a given phenomenon (Halldórsson *et al.*, 2007), this work adopted an open system approach, the industrial network approach and an abductive approach. Those approaches are further described below. Because this work did not aim to improve access management by outsourcing activities to decrease transaction costs, various other approaches were not considered: transaction cost analysis (Williamson, 1981); principal–agent theory (Eisenhardt, 1989) for designing contracts among actors to reduce asymmetric information, conflicting objectives or behaviour based on self-interest; the resource-based view (Barney, 1991) and relational view (Dyer and Singh, 1998) about outsourcing resources to achieve competitive advantages; and contingency theory (Hofer, 1990) for reorganising or changing how organisations are managed.

3.3.1 Open system approach

An open system approach is a sub-class within the systems approach (von Bertalanffy, 1969), also referred to as *systems theory* or *systems thinking* (Gammelgaard, 1997), which, by any name, has been acknowledged as a core theory in SCM and logistics (e.g. Bowersox and Closs, 1996; Lambert *et al.*, 1998b; Stock *et al.*, 1998; Stock and Lambert; 2001; Arlbjørn and Halldórsson, 2002). In particular, the open system principle can be fruitfully applied to describe and analyse how a system depends upon its environment (Arbnor and Bjerke, 2009), especially to reveal how changes in one part of the system impact its other parts (Burke, 2014). Described in Chapter 1, the system under study can indeed be viewed as an open system, for it depends upon its environment, which includes other systems: an SCM system, a logistics system and an intermodal transport systems (Ellram and Cooper, 1990; Woxenius, 1998; Stock and Lambert, 2001). Following calls to examine the concept of open systems to increase the visibility of SCM systems and extend holistic perspectives (Stock and Lambert, 2001), researchers have shown that an open system approach stresses the purposefulness and mechanics of SCM and logistics systems (Aastrup and Halldórsson, 2008) as well as intermodal transport systems (Woxenius, 1998).

3.3.2 Industrial network approach

The industrial network approach was expected to offer insights into their relationships, in a way similar to the principle of open systems in the sense that what happens between two organisations can affect their relationships with other organisations (Håkansson and Snehota, 1995). For the same reason, the industrial network approach has been applied in other research on intermodal transport (Woxenius, 1998; Stefansson and Lumsden, 2009; Sternberg *et al.*, 2013a). *Business relationships* are mutually oriented interactions among actors and are not just mechanisms enabling communication and information exchange among focal actors (Håkansson and Snehota, 1995), but are important processes that develop, change and evolve over time and affect actors, resources and activities (Håkansson *et al.*, 2009). What happens in business relationships reflects various technical, knowledge, social, administrative, and legal interdependencies on which every business builds (Håkansson and Snehota, 1995).

3.3.3 Abductive approach

Since the research undertaken was phenomenon-driven instead of theory-driven, it also adopted an abductive approach. The aim of abductive and inductive approaches is developing theory, whereas the aim of a deductive approach is to test theory (Arlbjørn and Halldórsson, 2002). Relative to an inductive approach, an abductive approach was considered, because theory development and empirical data collection occurred simultaneously, not in isolation, as an inductive approach would have accommodated (Dubois and Gadde, 2002); and because the primary aim was to expand current understandings of a phenomenon, not to generalise findings from empirical data (Kovács and Spens, 2005).

3.4 Research design

The section justifies choices made regarding the research design.

3.4.1 Method for the research design

A case study was considered to be the most appropriate method for the research owing to the nature of the RQs and the overall purpose of the thesis. As for the first reason, RQs can be descriptive, explorative or explanatory (Marshall and Rossman, 2014); explanatory research explains plausible relationships or explains patterns related to phenomena; explorative research investigates poorly understood phenomena to discover or identify important categories of meanings; and descriptive research describes phenomena. The RQs in this thesis ask either ‘what’ or ‘how’; whereas ‘what’ questions can be explorative or descriptive, ‘how’ questions can be explorative or explanative. Both types of questions are appropriate for qualitative research, which focuses on describing or exploring phenomena in depth (Ellram, 1996). Whereas ‘what’ questions are suitable for experimental methods (i.e. requiring control of behavioural events) and case studies (i.e. investigating a contemporary phenomenon in depth in a real-world context), as well as statistical tests of survey data, model building, simulations, archival analysis and historical studies (Bryman and Bell, 2011), ‘how’ questions are most suitable for experiments and case studies as well (Ellram, 1996; Yin, 2013). Thus, because the phenomenon under study was to be investigated in depth and without needing to control for behavioural events, a case study was thought to be the most appropriate means to address the RQs.

3.4.2 Unit of analysis

The primary unit of analysis in the case—that is, in the real-life phenomenon (Yin, 2013)—was access management for road hauliers and rail operators in intermodal freight terminals. The primary unit of analysis embedded subordinate units, or *embedded units of analysis* (Yin, 2013), in three case studies, each addressing one of the three RQs that, in turn, related to the elements of access in the overall analytical framework. Those elements of access helped to conceptualise access management from the perspective of road hauliers and rail operators in intermodal freight terminals. The embedded units of analysis are further described in relation to the three case studies in Section 3.5.

3.4.3 Model for the research design

Maxwell's (2013) model was chosen to guide the research process, for it adapts several components interactively developed to one another throughout the research process. By comparison, Flick's (2014) model begins with the RQs and proceeds with a sequence of decisions. Figure 7 depicts Maxwell's (2013) model with the components of the research conducted for the thesis.

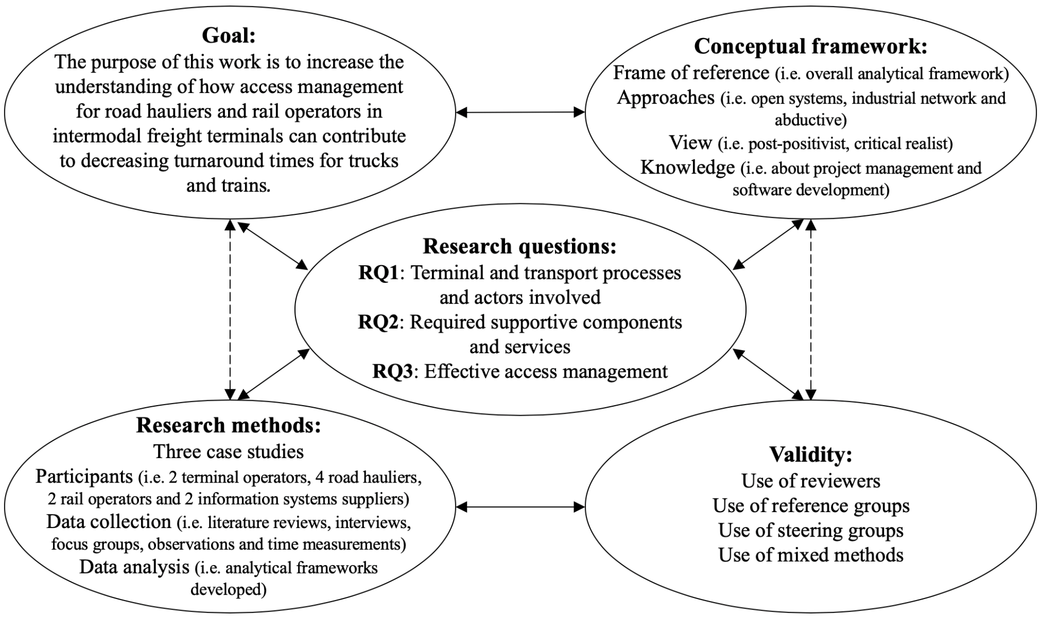

Figure 7. Interactive model of a qualitative research design (Maxwell, 2013)

The following sub-sections describe the components in relation to the research.

3.4.4 Goals

According to Maxwell (2013), *research-oriented goals* aim to achieve the research's purpose, *personal goals* motivate researchers and include the desire to improve or change a practice or situation involving them, and *practical goals* focus on accomplishing objectives. The overarching purpose of this thesis is to increase the understanding how access management for road hauliers and rail operators in intermodal freight terminals can contribute to decreasing turnaround times for trucks and trains. Meanwhile, as a researcher, the author's personal goals, include broadening personal academic skills and adding to personal knowledge by obtaining profound insights into access management for road hauliers and rail operators in terminals, including about access management services, information systems, ICT and information exchange. Last, the practical goals include enabling information exchange among the actors involved.

3.4.5 Conceptual framework

In general, a conceptual framework incorporates a frame of reference, research approaches and theories, philosophical beliefs and personal knowledge (Maxwell, 2013). The frame of reference for this thesis has been described in Chapter 2 and its research approaches and theoretical underpinnings described in Section 3.3. Regarding philosophical beliefs, the thesis has adopted a post-positivist view, which maintains a critical realist perspective on ontology and a modified objectivist perspective on epistemology (Guba, 1990). According to Guba (1990), critical realism holds that 'reality exists but can never be fully apprehended' and 'is driven by natural laws that can only be incompletely understood', whereas modified objectivism holds that 'objectivity remains a regulatory ideal, but it can only be approximated, with special emphasis placed on external guardians such as the critical tradition and the critical community'. Critical realists also conceive the world as an open system (Aastrup and Halldórsson, 2008) and advocating taking an abductive approach to understand it. Last, the author's personal knowledge stems from experience with managing various industrial research projects and developing software for intelligent transport systems that incorporate wireless communication between infrastructure and vehicles, the models for which embody different layers and hierarchies, as in the TCP/IP layer model (Braden, 1989) and the transport layer model (Figure 4). As part of that personal knowledge, the author maintains that knowledge is best gained from the interaction of objectivity and subjectivity and that researchers can expand knowledge by performing both interviews and measurement.

3.4.6 Research questions

In Maxwell's (2013) model, RQs are central. Unlike in other models, in which RQs are formulated at the outset of research and remain fixed, Maxwell (2013) encourages researchers to reformulate their RQs throughout the research process in light of the other key components of the research process. To develop RQs, Maxwell (2013) proposes four steps: identifying new questions about topics not fully understood (see Section 1.4), considering the research's goals and formulating RQs designed to achieve the research's overall purpose (see Section 1.4), taking the relationship between RQs and methods into account (see Section 3.4.7) and ensuring the validity of findings meant to answer the RQs by reflecting on their potential inaccuracy or inapplicability (see Section 3.6).

3.4.7 Research methods

The three RQs were respectively addressed in Study 1, Study 2 and Study 3. The following paragraphs describe the selection of participants, data collection and analysis in the studies, each of which is elaborated upon in Section 3.5.

Selection of participants

Collecting empirical data in the three studies involved engaging with various participants: four road hauliers (i.e. Road Hauliers A, B, C and D), two rail operators (i.e. Rail Operators A and B), a railroad terminal operator (i.e. Railroad

Terminal Operator), a seaport terminal operator (i.e. Seaport Terminal Operator) and two information system suppliers (i.e. Information System Suppliers A and B). All participants are further described in Appendix A. The selection of the terminal operators followed a purposive sampling strategy—that is, involved selected settings, people or activities to provide information relevant to fulfilling the research's goals and answering the RQs (Maxwell, 2013). To be specific, the railroad terminal and the seaport terminal were chosen because they are major terminals in Sweden, and the Seaport Terminal Operator was chosen given her/his accumulated expertise in access management services.

By extension, the four road hauliers and two rail operators were selected based on referrals from the Railroad Terminal Operator and Seaport Terminal Operator as part of a snowballing strategy, in which sampling follows from initial contact with people who recommend contact with others (Bryman and Bell, 2011). The Seaport Terminal Operator recommended gaining insights from several road hauliers and rail operators to form a better understanding about the phenomenon under study. Both terminal operators provided statistical data on road hauliers and rail operators that used the terminal, which precluded having to measure non-participants. Last, following a purposive sampling strategy, Information System Suppliers A and B were selected due to their expertise in developing fleet management systems. Table 2 describes participants involved in the seaport and railroad terminal set-ups.

Table 2. Participants in the seaport terminal and railroad terminal set-ups

Set-up	Terminal operator	Small-scale transport operators
Seaport terminal set-up	Seaport Terminal Operator	Road Hauliers A, C and D Rail Operators A and B
Railroad terminal set-up	Railroad Terminal Operator	Road Hauliers A and B

Data collection

Literature reviews were conducted to gain a more in-depth understanding of access management. Only peer-reviewed works published between 2000 and 2019 were included in the reviews. Aside from using Google Scholar and the search engine of Chalmers Library, searches were conducted in three databases: Web of Science, Scopus and ABI/Inform. Different keywords and search strings were used for the different topics. For example, the search for published works addressing access management applied the following keywords and search strings: 'transport*' AND ('freight' OR 'logistics') AND ('access management' OR 'arrival process*' OR 'appointment system' OR 'truck arrival' OR 'lorry arrival' OR 'slot allocation' OR 'truck scheduling' OR 'lorry scheduling'). The database searches returned 287 results, which were reduced to 30 after the abstracts were read and the number of citations taken into account. The same procedure was applied to locate published works addressing the other three elements of access (i.e. access network structure, access management components and access management services). Of course, the searches could not have identified all published works on those topics from the period, especially because access management and elements of access are represented by a range of terminology. For instance, regarding access management services, literature on pre-notification and appointment services often interchangeably uses terms such as 'gate appointment', 'truck appointment', 'vehicle booking' and 'truck scheduling'. Therefore, to cover the most important, most relevant literature, a snowballing strategy was applied, in which relevant articles and authors in the reference lists of applicable search results were searched for as well.

Other sources of data were interviews, focus groups, participant observations and a mixed-methods approach. First, interviews were conducted with individuals functioning within the seaport terminal and railroad terminal set-ups. In general, interviews were conducted because they constitute the most important source of evidence in case studies (Yin, 2013). The interview questions derived from the RQs (Maxwell, 2013) and were further developed based on the literature reviews and the frame of reference. As a result, three interview guides were created (see Appendix C): Interview Guide 1, which focused on information exchange among the participants; Interview Guide 2, which focused on how the terminal and transport processes involved can be managed effectively; and Interview Guide 3, which focused on how effective access can be managed. The interviews were semi-structured to ensure flexibility and allow supplementary questions and topics to be addressed (Flick, 2014). Second, focus groups were held to challenge how participants have collectively made sense of the phenomenon and constructed meanings about it (Bryman and Bell, 2011). The focus groups involved identifying participants' problems with access management and brainstorming possible solutions. Third, participant observations were performed as a powerful means to gain in-depth understanding about everyday life situations (Flick, 2014). Involving both on-site visits at the seaport and railroad terminals under study and accompanying truck drivers on their routes, the observations focused on the terminal and transport processes involved in particular depth. Fourth and last, as part of a mixed-methods approach to collect both quantitative and qualitative data (Flick, 2014), time measurements were taken in Study 3, along with interviews, to gain a more complete understanding of how real-time information exchange can help to decrease turnaround times (Creswell, 2014).

Data analysis
The empirical data were analysed with the aid of various coding strategies after field notes from the participant observations and notes from the semi-structured interviews were transcribed. Coding methods that assigned labels to segments of data to allow simultaneously categorising, summarising and accounting for each piece of data (Flick, 2014) were applied. Thematic coding was also applied to develop categories (Flick, 2014), all based on previous results, approaches and theories (see Section 3.3) as well as empirical data from the three studies conducted. In total, six analytical frameworks were developed. Spreadsheets was used to support analyse and construct matrices.

3.5 Studies

This section describes Study 1 (i.e. on the access network structure), Study 2 (i.e. on access management components and services) and Study 3 (i.e. on effective access management). The studies resulted in five research papers, all appended to this thesis. Table 3 shows how the studies, their purposes, methods and analyses related to the RQs, the embedded units of analysis and the appended papers.

Table 3. RQs, studies, embedded units of analysis and papers

RQ	Study 1: Access network structure			Embedded units of analysis	Papers
	Purpose	**Methods**	**Analysis**		
RQ1: Terminal and transport processes and actors involved	To exploratively describe and identify terminal and transport processes	30 observations at terminals and in trucks	Process reference model	Terminal and transport processes	Paper 5
	To exploratively identify the actors involved and their (lack of) information exchange	11 semi-structured interviews	Industrial network approach and spreadsheet to support analysis	Actors involved and their information exchange	Paper 1
RQ	**Study 2: Access management components and services**			**Embedded units of analysis**	**Paper**
	Purpose	**Methods**	**Analysis**		
RQ2: Required supportive information components and services	To exploratively identify required information systems and ICT applications	5 focus groups	Typology reference model and spreadsheet to support analysis	Information systems and ICT applications	Paper 4
	To exploratively identify the required and most relevant information attributes to be exchanged in real time	7 focus groups and a telephone group meeting	Information attributes framework and real-time information exchange framework	Required and most relevant information attributes for real-time information exchange	Papers 1 and 3
	To exploratively identify the required access management services	Review and synthesis of relevant literature	Differentiation framework	Access management services	Paper 2
RQ	**Study 3: Effective access management**			**Embedded units of analysis**	**Papers**
	Purpose	**Methods**	**Analysis**		
RQ3: Effective access management	To explain how effective automatic information exchange can be managed	4 focus groups	Cost–benefit matrix	Information attributes and phases of automatic exchange	Paper 4
	To explain how the terminal and transport processes involved can be effectively managed	8 semi-structured interviews and 4 focus groups	Process analytical framework and spreadsheet to support analysis	Terminal and transport processes	Paper 5
	To explain how effective access can be managed	9 semi-structured interviews, 2 focus groups, 198 hours of time measurements, and 25 observations in trucks	Differentiation framework and spreadsheet to calculate mean, median, min, max and standard deviation	Turnaround times for trucks and trains	Papers 2 and 3

A timeline of the studies and papers appears in Appendix B. Each study is briefly described in the three sub-sections below.

3.5.1 Study 1: On the access network structure

Addressing RQ1, Study 1 involved using descriptive and exploratory methods to identify and describe (1) the terminal and transport processes involved and (2) the actors involved and their information exchange, or lack thereof. To identify those processes, 30 participant observations at the seaport and railroad terminals were performed by the author and 25 members on the research team. Via purposive sampling, personnel who met certain criteria (e.g. background, gender and knowledge about the phenomenon under study) were selected to be observed. The selection of truck drivers to observe also followed purposive sampling based on criteria such as gender, language, behaviours as drivers, driver training and regularity of trips. Accompanying the drivers on their trips provided opportunities for conversation to obtain additional in-depth information. Aside from field notes taken during conversations and observations, photos and short movies were also taken, namely with a smartphone. To identify the actors involved and their information exchange, 11 semi-structured interviews guided by Interview Guide 1 (see Appendix C) were conducted at different times. The interviewees were selected from the participating organisations by following convenience sampling, and all interviews were recorded on a smartphone and later transcribed.

Data transcribed from the field notes were coded into three categories—actors, activities and resources—taken from the industrial network approach (Håkansson and Snehota, 1995). Applying the industrial network approach together with Davenport's (1993) definition of *process*, a process reference model was developed. As detailed in Paper 5, the process reference model allowed an in-depth analysis of the processes involving the major activities and resources of the actors studied. The industrial network approach was also applied to analyse the data collected from the semi-structured interviews that contained in-depth information about how the participants exchange information with each other. Last, spreadsheets were used to construct a matrix able to sort the most important data from the interviews by categorising the actors, activities and resources into sub-categories to identify which actors exchange what information with one another.

3.5.2 Study 2: On the access management components and services

Addressing RQ2, Study 2 involved exploratively identifying (1) components of access management required to enable access to resources at terminals (i.e. information systems and ICT applications), along with the required and most relevant information attributes to be exchanged in real time, and (2) the access management services required to enable effective access to resources at terminals. To identify those services, relevant literature was reviewed and synthesised for later reference. Meanwhile, to identify the required access management components, 12 focus groups were held at different times over a 22-month period. The first five focus groups discussed how the participants' information systems can become interoperable and thereby enable automatic information exchange; the next five focus groups sought to identify information attributes required to enable access to resources at terminals; and the final two focus groups, as well as the telephone group meeting, aimed at selecting the information attributes that were most relevant to real-time information exchange. In all groups, participants were selected from the participating organisations by way of convenience sampling. All focus groups were recorded on a smartphone, and meeting notes were taken during the telephone group.

All transcripts and notes were coded and analysed. When data from the focus groups purporting required information systems and ICT applications were analysed, they were coded into the categories 'information systems' and 'ICT applications' by applying the typology reference model developed in Paper 4 and synthesised from relevant literature (e.g. Buijs and Wortmann, 2014; Marchet *et al.*, 2009; Marchet *et al.*, 2012). By contrast, data regarding the required information attributes were coded into sources and types of information attributes; the sources were subdivided into actors, activities and resources, with reference to the industrial network approach (Håkansson and Snehota, 1995), whereas the types were subdivided into static, historical and dynamic (i.e. real time) following Giannopoulos (2004); Burstein and Holsapple (2008). As a result, an analytical framework, called the 'information attributes framework', was developed, as described in Paper 1. Data regarding the most relevant information attributes were coded into the categories 'ITU flows', 'request messages', and 'response messages'. Last, another analytical framework, called the 'information exchange framework', was developed, as described in Paper 3.

3.5.3 Study 3: On the effective access management

Addressing RQ3, Study 3 involved explanatory research to investigate (1) how effective automatic information exchange can be managed, (2) how the terminal and transport processes involved can be effectively managed and (3) how effective access can be managed. First, to gain insights into effective automatic information exchange, four focus groups were held at four different times over an eight-month period. The discussions in the focus groups centred on how and when the information attributes need to be exchanged by the access management services in order to enable effective access to resources at terminals. Second, to gain insights into how the terminal and transport processes can be effectively managed, eight semi-structured interviews and four additional focus groups were conducted, also at different times. The interviews followed Interview Guide 2 (see Appendix C), while the focus groups concentrated on what activities and resources could be affected by access management services planned for future use. Third and last, to gain insights into how effective access can be managed, six additional semi-structured interviews and two more focus groups were conducted, again at different times. Those interviews followed Interview Guide 3 (see Appendix C), whereas the focus groups centred on the potential effects of access management services planned for the future. During data collection, a real-time information exchange platform service was developed that was tested with time measurements purporting truck drivers' activities and evaluated by conducting three semi-structured interviews. All participants in the focus groups and interviewees were selected from participating organisations by way of convenience sampling, and all focus groups and interviews were recorded on a smartphone and later transcribed.

Data collected regarding effective automatic information exchange were coded as either costs or benefits, following Kraljic's (1983) model of supplier relations. That model and a cost–benefit analysis with reference to Mishan and Quah (2007) formed the body of knowledge used to construct a cost–benefit matrix, as described in Paper 4. To analyse the data concerning the effective management of the terminal and transport processes involved, the process analytical framework, developed in Paper 5, was applied together with spreadsheet such that a matrix was constructed with four columns: 'access management services', 'pre-access phase', 'access phase' and 'post-access phase'. Within each access phase, the effective activity performance and resource utilisation were analysed. Next, for each access management service, the effective activity performance and resource utilisation for each access phase were also analysed. To analyse the data regarding how effective access can be managed, an analytical framework called the 'differentiation framework', as elaborated in Paper 2, was developed to differentiate the five identified services in terms of the four key performance indicators (i.e. turnaround time, access reliability, access precision and access flexibility). To analyse the effects of the developed access management service, the mean times, as well as each median, min, max and standard deviation, were calculated in spreadsheet.

3.6 Validity of the research

According to Guba and Lincoln (1989), four conventional criteria of research quality—internal validity, reliability, external validity and objectivity—have parallel criteria that are considered to better accommodate qualitative research: credibility, transferability, dependability and confirmability. First, *credibility* refers to the fit between respondents' and researchers' constructions of reality (Halldórsson and Aastrup, 2003). Briefly put, credibility supports in-depth understandings and meanings of phenomena studied. Second, *transferability* focuses on the possibility of making general claims about the world (Bryman and Bell, 2011). Precluding true (statistical) generalisations, however, when sampling is not randomised, transferability means applying knowledge gained outside the context of the phenomenon studied, or what has been described as *analytical generalisation*, which aims is to generalise findings to other concrete situations and contribute to theory building (Yin, 2013). Part of the theory-building process, by extension, is formulating propositions that are statements, grounded in the findings, intended to answer RQs (Maxwell, 2013). Third, *dependability* indicates the stability of data over time (Guba and Lincoln, 1989) and can be improved by tracking variance, especially by documenting a research process in terms of methods, participant selection, field notes, interview guides and interview transcripts (Bryman and Bell, 2011). Fourth and final, *confirmability* gauges the extent to which findings are based on data and requires reference to external sources. Since interpretations and recommendations are part of all qualitative research, researchers need to provide evidence of their sources (Halldórsson and Aastrup, 2003), and to ensure the robustness of their results, they can have their research processes externally audited. Table 4 describes how the four conventional criteria of research quality were pursued in the research conducted for the thesis.

Table 4. Conventional criteria of research quality in relation to the thesis

Criteria	**Relation to the research**
Credibility (i.e. internal validity)	For all three studies, the findings were validated by presenting and discussing them with the participants, all of whom took part in data collection in all three studies, were well-informed of the research's purpose and were well-instructed by user manuals and oral explanations. In Study 1, participant observations were conducted to gain in-depth insights into the studied phenomenon, whereas in Study 2, focus groups were conducted to challenge and to probe participants' reasons for holding certain views on the interoperability of their information systems and to collectively identify the required and most relevant information attributes to be exchanged among each other. In Study 3, results of the time measurements were validated during semi-structured interviews with participants, for what amounted to a triangulation of sources. Triangulation was also performed during participant observations, either with conversations with truck drivers or with interviews with participants.
Transferability (i.e. external validity)	The analytical frameworks and reference models developed in all studies were based on the literature and other research approaches and theories, as well as developed to be transferable to other settings (e.g. with other road hauliers, rail operators and terminal operators). The developed frameworks include access management services in use at other terminals around the world, and nothing indicates their inapplicability at other terminals in other settings. All five papers were subjected to double-blind reviews, revised in light of critical comments and presented and defended at international research conferences. The findings from the papers resulted in the formulation of six propositions as part of the theory-building process for analytical generalisation.
Dependability (i.e. reliability)	The interviews in all studies followed interview guides (i.e. Interview Guide 1 in Study 1 and Interview Guide 2 and 3 in Study 3) developed in light of the RQs and literature. The interviews in Studies 1 and 3 and focus groups in Studies 2 and 3 were recorded and transcribed. All participants were selected by way of purposive sampling, snowballing or convenience sampling. During participant observations in Study 1, field notes, photographs and videos were taken. In Study 3, all time measurements were stored in a digital file. The designs, methods and processes in all studies, as well as their rationales, were well-documented and can be followed in detail.
Confirmability (i.e. objectivity)	Taken together, the three studies involved two reference groups and a steering group. The reference groups acted operationally in the studies and furnished empirical data as they were interviewed, participated in the focus groups, took part in designing and developing access management services and helped with the time measurements. By contrast, the steering group discussed and provided a wider perspective on the effects of the research. Each group met twice annually to review the findings and discuss both prior and future research actions to ensure that the findings were confirmable and that the research was focused, relevant and of interest.

In sum, the quality of the research conducted for this thesis was ensured by carefully addressing (1) the credibility of its findings via validation processes, (2) its transferability by developing analytical frameworks to be transferred to other settings, (3) its dependability by developing interview guides and applying well-known sampling strategies and (4) its confirmability by hosting reference and steering groups to guide the research and confirm its findings.

4 Summary of appended papers

This chapter summarises the five appended papers that form the foundation of this thesis.

4.1 Overview of the appended papers

Table 5 presents an overview of the five appended papers in terms of their approaches, findings and contributions.

Table 5. Summary of the five papers

Paper	Approach	Findings	Contribution
Paper 1	**Purpose**: To identify current and required information attributes **Method**: 11 semi-structured interviews and 5 focus groups	The identification of current and required information attributes, and poor information exchange among the actors involved.	**Theoretical**: Information attributes framework **Managerial**: Exchanging the required information attributes can decrease turnaround times.
Paper 2	**Purpose:** To explore how the 5 identified access management services can affect access performance **Method:** 6 semi-structured interviews and 2 focus groups	Access management services able to exchange information in real time can improve more access performance indicators.	**Theoretical**: Differentiation framework **Managerial:** Identifying services with the most potential can decrease turnaround times.
Paper 3	**Purpose**: To design an access management service that can improve road haulage activities **Method:** 2 focus groups, 1 telephone group meeting, 3 semi-structured interviews, 198 h of time measurements and 25 observations and interviews	The design service can exchange real-time information attributes identified as being the most relevant (i.e. ITU status, queueing status and ETA) and dramatically lower barriers to adopting new services.	**Theoretical:** Real-time information exchange framework **Managerial:** Exchanging the most relevant information attributes in real time can decrease turnaround times.
Paper 4	**Purpose:** To explore how and when the most beneficial and cost-effective information attributes can be automatically exchanged **Method:** 9 focus groups	The most beneficial, cost-effective information attributes identified need to be exchanged a week before, a day before and 2 hours before accessing ITUs to enable effective access to resources at terminals.	**Theoretical:** The typology reference model and the cost–benefit matrix **Managerial:** Planning access to ITUs more efficiently can decrease turnaround times when actors follow the proposed exchange of identified information attributes.
Paper 5	**Purpose:** To clarify how terminal and transport processes can be managed effectively **Method:** 30 observations, 8 semi-structured interviews and 4 focus groups	Effective activity performance and resource utilisation can (1) eliminate the needless moving, lifting and shifting of ITUs at terminals, (2) facilitate the use of electronic paperwork and (3) allow the digital inspection of ITUs.	**Theoretical:** The process reference model and the process analytical framework **Managerial:** Services with the most potential to contribute to effective activity performance and resource utilisation can be identified.

4.2 Paper 1: 'Access management in intermodal freight transportation: An explorative study of information attributes, actors, resources and activities'

The lack of high-quality, real-time information exchanged between road hauliers, rail operators and terminal operators negatively affects their access management. In response, Paper 1 sheds light on information attributes currently exchanged and ones that should be exchanged to enable effective access to resources at terminals. A case study, consisting of a literature review, semi-structured interviews and focus groups with key stakeholders, resulted in a comprehensive compilation of what information attributes exist and are required. The paper reveals that the most useful information attributes required for the future are pick-up time, loading point at terminals, unloading point at terminals, occupancy rate, queuing status and ITU status. With such information, road hauliers can reschedule their trucks to avoid congestion at terminals and lower the number of empty runs. Paper 1 also indicates that the current information exchange between participants is either poor or very poor. The paper's chief theoretical contribution is the development of the information attributes framework, which visualises the existing and required information attributes on the basis of the relationship between actors, resources and activities, categorised as static, historical or dynamic. Its chief managerial contribution, by contrast, is that transport planners at hauliers and personnel at terminals can learn how to improve their information exchange and what information attributes need to be exchanged in order to enable effective access to resources at terminals and, in turn, decrease turnaround times for trucks and trains.

4.3 Paper 2: 'Differentiation of access management services at seaport terminals: Facilitating potential improvements for road hauliers'

Because literature on categorising and differentiating access management services remains scant, Paper 2 examines how the five identified access management services can be differentiated in terms of four defined access performance indicators: turnaround time, access reliability, access precision and access flexibility.[1] A case study, consisting of semi-structured interviews and focus groups, revealed that access management services that allow exchanging information in real time (e.g. with real-time information exchange platform services and dedicated access services) can improve a greater number of access performance indicators: decreased turnaround times for trucks and trains at terminals; increased reliability of access due to the exchange of notices about ITU statuses, paperwork and resource statuses throughout the terminal and transport processes; more precise access through the exchange of estimated times of arrival (ETA) and ITU ID so that terminal operators can begin preparing access for the on-time delivery of those ITUs; and more flexible access due to the ability to inform other actors when unforeseen events occur during terminal and transport processes. The paper's theoretical contribution is the development of the differentiation framework, which can help in determining which access

[1] In this thesis, the 'access service elements' are referred to as 'access performance indicators', because they are measures of effective access management (see Section 5.3.3).

management service can best improve the access process at certain seaport terminals given their particular customers. For managers, the differentiation of five access management services revealed that services that allow exchanging information in real time (e.g. real-time information exchange platform services and dedicated access services) have greater potential than the others to decrease turnaround times and increase the reliability, precision and flexibility of access.

4.4 Paper 3: 'Potential improvements for access management in intermodal freight terminals: Designing and testing a service for small road haulers'

Whereas research has predominantly focused on larger organisations such as seaport terminal operators when designing and developing new access management strategies, it has altogether neglected small road hauliers. Therefore, Paper 3 presents an access management service designed for small road hauliers and tested in real-life situations to gauge its potential to improve road haulage activities. A real-life case study, consisting of semi-structured interviews, focus groups, a telephone group meeting, time measurements and observations concerning road haulage activities, resulted in the identification of the most relevant information attributes to be exchanged in real time (i.e. ITU ID, ITU status, ETA, queueing status and weighing status), as well as revealed that the major inefficiencies of truck driver activities (i.e. waiting and administration time 31% of the time) can be decreased if the actors involved are willing to use and adopt the designed access management services. The paper's theoretical contribution is the development of the information exchange framework, which categorises the most relevant information attributes required, explains how those attributes need to be exchanged in real time and distinguishes import from export flows of ITUs. The managerial implications suggest a novel understanding of how to improve the abilities of the different identified access management services and of how the relevant information attributes need to be exchanged in real time to decrease turnaround for trucks and trains.

4.5 Paper 4: 'Automatic information exchange between interoperable information systems: Potential improvement of access management in a seaport terminal'

To date, research has rarely focused on reducing the lack of high-quality, real-time information exchange caused by incompatible information systems, especially not by identifying how and when information needs to be automatically exchanged. Thus, with reference to a case study at a seaport terminal involving nine focus groups, Paper 4 identifies how and when the most beneficial, cost-effective information attributes (i.e. deviation information, direction, driver ID, ETA, goods priority information, ITU ID, ITU status, opening hours, shipment ID and vehicle ID) need to be automatically exchanged between interoperable actors' information systems in order to decrease turnaround. Those attributes need to be exchanged a week before, a day before and two hours before the ITUs are retrieved at the terminal. The paper's theoretical contributions are twofold: (1) the typology reference model, which synthesises relevant literature and describes how interoperable information systems and ICT applications can automatically exchange those attributes through EDI or XML, and (2) a cost–benefit matrix that identifies and structures the information attributes into different categories, from low cost and low benefit to high cost and high benefit. The matrix, as a change management tool, can also be deployed to identify and support the transformation of attributes from one category to another, especially from high cost to low cost and from low benefit to high benefit, as data-processing tools and techniques evolve. Moreover, the matrix can be used to classify data sources to ensure that sufficient resources are deployed for automatic information exchange and that unnecessary collection is avoided. Last, the paper's contributions for managers include new knowledge for decision-making about what information needs to be considered and what technologies are available for performing automatic information exchange as a means to contribute to decreasing turnaround times for trucks and trains.

4.6 Paper 5: 'Managing terminal and transport processes with access management services'

Because previous research has largely focused on decreasing turnaround times by implementing access management services, it has overlooked those services' potential effects on activity performance and resource utilisation. The purpose of Paper 5 is thus to clarify how a seaport terminal can use access management services to organise terminal and transport processes for effective activity performance and resource utilisation. A case study conducted at a seaport terminal and consisting of participant observations, semi-structured interviews and focus groups revealed that real-time information exchange platform services and dedicated access services have the greatest potential to improve processes. As a result, wait times for truck drivers and train drivers at the terminal can be reduced, because straddle carriers can operate effectively as they receive relevant information in advance that allows them to reduce the needless moving, lifting and shifting of ITUs at the terminal. The wait time for truck and train drivers can also be cut because container inspection times can be reduced by replacing manual inspections with inspections via sensors and cameras. Without manual inspection, the number of administrators and controllers at the terminal operators can be reduced. In light of those results, the paper's theoretical contributions are a reference model and an analytical framework synthesised from the literature. The model maps and details the terminal and transport processes involved, whereas the framework depicts and analyses the relationships between those processes, access management services, activity performance and resource utilisation. The paper's managerial contribution is new knowledge for planning managers—to wit, that access management services able to exchange information in real time have the greatest potential to achieve effective activity performance and resource utilisation.

5 Results

This chapter presents the findings from the five appended papers that in turn answer the three RQs.

5.1 Relationships between the appended papers and the research questions

The relationships between the papers and RQs using the overall analytical framework appear in Figure 8.

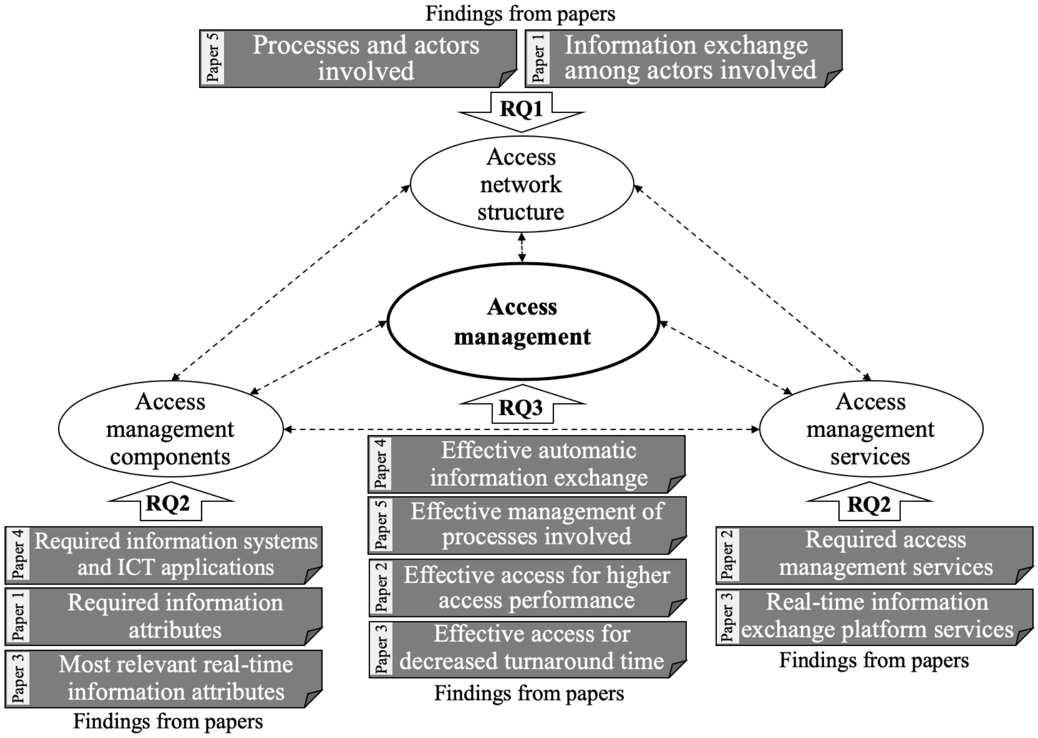

Figure 8. Relationships between the papers and RQs in the overall analytical framework

In Figure 8, the primary findings from each paper appear in the grey boxes. As the figure show, each paper contributes to answering more than one RQ. For example, Paper 5 contributes to answering RQ1, by describing and identifying the terminal and transport processes and the actors involved, and to an answering RQ3, by explaining how those processes can be managed effectively.

Table 6 provides a detailed summary of how the findings from the papers answer the various aspects of the RQs as articulated in Section 1.4.

Table 6. A summary of the results of each RQ

RQ1: What processes and actors are involved in accessing resources at intermodal freight terminals?		
Aspects	**Papers**	**Results**
Terminal and transport processes involved	Paper 5	Identification of activities and resources in the terminal and transport processes involved in the access of resources in the seaport terminal and railroad terminal set-ups.
Actors involved	Papers 1 and 5	Actors involved are road hauliers, rail operators, and the seaport and railroad terminal operators. In the seaport terminal set-up, information exchange occurs between the actors involved but not in real time. In the railroad terminal set-up, no information exchange occurs among the actors involved.
RQ2: What supportive information components and services are required to enable effective access to resources at intermodal freight terminals?		
Aspects	**Papers**	**Results**
Required information systems and ICT applications	Paper 4	The information systems and ICT applications required to enable interoperable information exchange by using EDI or XML are a transaction-processing system and supply chain execution applications.
Required and most relevant information attributes	Papers 1 and 3	All information attributes requiring to be exchanged to enable effective access to resources at terminals are identified. Of them, the most relevant ones (i.e. ITU ID, ITU status, ETA, queueing status and weighing status) suitable to be exchanged in real time are selected.
Required access management services	Paper 2	Differentiated by ability to exchange or share information in real time, the access management services required to enable effective access to resources at terminals are dedicated access services (exchange), real-time information exchange platform services (exchange), pre-notification and appointment services (share), automated gate services (share) and information access services (share).
RQ3: How can effective access to resources at intermodal freight terminals be managed?		
Aspects	**Papers**	**Results**
Effective automatic information exchange	Paper 4	For effective access management, the right information needs to be automatically exchanged at the right time. More specifically, the right information attributes are the most beneficial and cost-effective (i.e. deviation information, direction, driver ID, ETA, goods priority information, ITU ID, ITU status, opening hours, shipment ID and vehicle ID), whereas the right time is a week, a day and 2 hours before access to resources is granted or received.
Effective management of terminal and transport processes	Paper 5	Access management services can be used to effectively manage the terminal and transport processes in order to achieve effective activity performance and resource utilisation. Loading and unloading activities at terminals can be performed effectively with less moving and lifting of containers and fewer drivers, administrators and controllers.
Effective access	Papers 2 and 3	Access management services can enable effective access to resources at terminals as a means to contribute to higher access performance, meaning that more access performance indicators can be affected: decreased turnaround times, increased access reliability (i.e. access to the right resources), access precision (i.e. access at the right time) and access flexibility (i.e. ability to update other actors when unforeseen events occur).

The answers to each RQ are further described in the next three sub-sections.

5.2 RQ1: Terminal and transport processes and actors involved

The following section presents the findings from Papers 1 and 5 in answer to RQ1.

5.2.1 Terminal and transport processes

The processes involved in the access of resources at terminals include both the transport processes of road hauliers and rail operators and the terminal processes of seaport and railroad terminal operators. Those processes and their corresponding activities and resources can be classified and analysed in three phases: pre-access, access and post-access. Pre-access involves all of the planning and coordination activities that the actors need to perform and all of the resources that they need to utilise in order to be able to grant or receive access to specific resources (e.g. ITUs, loading bays and entry lanes) at terminals at certain times of day. Later, post-access involves all activities and resources needed to finalise the handling of specific resources after they have been accessed.

In the seaport terminal set-up

In the pre-access phase of the seaport terminal and road transport processes, the Seaport Terminal Operator plans the placement of ITUs, while the road hauliers coordinate their trucks and drivers to drop off and/or pick up ITUs. In the access phase, which begins when trucks arrive at the terminal, the truck drivers need to stop at the marshalling area (i.e. where they wait to enter the terminal area) and the control area (i.e. where ITUs are inspected by controllers and administrators who enter information about the ITUs into the information system). The information system notifies the straddle carrier drivers to start unloading or loading the ITUs. After loading or unloading, the truck drivers drive to the exit gate and register any ITUs that they have picked up. In the post-access phase, which begins when the trucks exit the terminal area, the truck drivers first notify the transport planner, who in turn informs their customers that the ITUs are in transit and gives them an ETA. Meanwhile, the straddle carrier drivers place the newly received ITUs in the yard.

In the pre-access phase of the seaport terminal and rail transport processes, the rail operators prepare for the ITUs to be delivered and picked up at the terminal, after which they inform the Seaport Terminal Operator about the ITUs to be dropped off and delivered. In response, the Seaport Terminal Operator coordinates dispatchers and straddle carrier drivers to begin moving the prepared ITUs from the yard to the train platform. As a result, more than 50% of all ITUs are already in place when the train arrives at the terminal. The access phase commences when the train arrives at the terminal, at which point the Seaport Terminal Operator inspects the train and the ITUs, shunts the train from an electric locomotive to a diesel-driven one, manually (dis)confirms that the received ITUs are the ones prepared for and unloads and loads all confirmed ITUs. Following that process, the Operator manually checks that the loaded ITUs match the ones to be transported, re-shunts the train from diesel to electric and conducts a safety inspection. Before the train departs, the train driver conducts a final safety inspection of the train and all ITUs to be transported. Once the train departs, the post-access phase begins, at which point the straddle carrier drivers move newly received ITUs into the yard as the train drivers convey the trains back to their terminals.

In the railroad terminal set-up
The road and terminal processes in the railroad terminal set-up are similar to their corresponding processes in the seaport terminal set-up. Differences between the set-ups include that the railroad terminal uses reach stackers to tranship ITUs between trucks and trains, whereas the seaport terminal uses straddle carriers, and uses neither a marshalling area nor a border gate in the access phase. The railroad terminal lacks a border gate because it does not export any ITUs and, for that reason, does not require security control as vigorous as what the Seaport Terminal Operator requires. Beyond those differences, the activities and resources in the road transport and terminal processes in the railroad terminal set-up are performed and utilised similarly to those in the seaport terminal set-up.

5.2.2 Actors involved

The actors involved in accessing resources at terminals are road hauliers and both rail and terminal operators. Their information exchange, which depends upon their business relationships as mechanisms for enabling information exchange (see Section 3.3.2), is elaborated upon in the following paragraphs.

In the seaport terminal set-up
In the seaport terminal set-up, no information exchange occurs between the four road hauliers and the Seaport Terminal Operator due to the lack of business relationships among them. Instead, information is exchanged between the shipper and the road hauliers and between the shipper and the Seaport Terminal Operator, because those actor dyads have business relationships with each other. The Seaport Terminal Operator and the two rail operators, however, do exchange information, because they have business relationships based on predefined schedules of train arrivals at the terminal. As a result, they can inform each other when changes occur so that the trains no longer need to follow the predefined schedules. The Seaport Terminal Operator also receives notices from the rail operators about which ITUs are loaded on arriving trains and which ITUs need to be loaded onto departing trains to be transported back to the rail operator. However, that information is typically received too late by the Seaport Terminal Operator to be able to prepare all ITUs to be loaded onto arriving trains. As a consequence, ITUs are often needlessly stacked and lifted in the seaport terminal area.

In the railroad terminal set-up
Information exchange also does not occur among the four road hauliers and the Railroad Terminal Operator because they do not maintain any business relationships Consequences of their poor information exchange include that trucks need to return empty to the road haulier's terminal if they arrive at the railroad terminal and cannot access certain ITUs for pick up. Moreover, long wait times typically occur for trucks at the railroad terminal, because the road hauliers do not receive any exact ETAs for the freight trains. Worse still, when the hauliers do receive information about the delayed arrivals of freight trains, they do not trust that information. Too often, they have been notified by the Railroad Terminal

Operator that a certain train will be delayed, only to arrive at the later ETA and realise that the train was in fact on time.

5.3 RQ2: Required supportive information components and services

This section presents the findings from Papers 1, 3 and 4 to answer RQ2.

5.3.1 Required information systems and ICT applications

Figure 9 (taken from Paper 4) presents the information systems (in grey boxes) and the ICT applications (in italics) required to enable interoperable information exchange. One such system—namely, an application programming interface (API), the MyMo API—developed by the Information System Supplier B, which is based on information systems (e.g. transaction-processing systems) and ICT applications (e.g. supply chain execution applications). MyMo API can enable automatic information exchange among the actors involved via either EDI or XML.

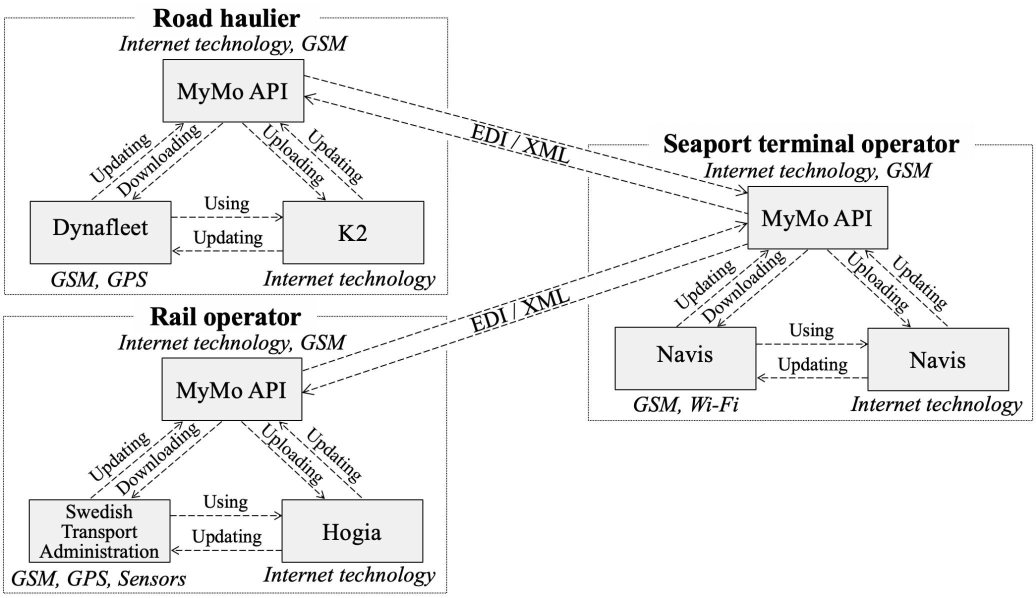

Figure 9. Information systems and ICT applications required to enable actors to access resources at terminals

K2, Hogia and Navis are decision support systems used by the road hauliers, rail operators and the Seaport Terminal Operator, respectively, that can update MyMo API with information to be automatically exchanged among the actors. Dynafleet, the Swedish Transport Administration and Navis are real-time systems that update MyMo API with information gained from sensors in vehicles and at terminals. As a result, MyMo API enables automatic information exchange between the Seaport Terminal Operator and both the rail operators and the road hauliers. The automatic information exchange is triggered by different EDI request messages when the status of information attributes changes.

5.3.2 Required and most relevant information attributes

A comprehensive list of information attributes that require to be exchanged to enable effective access to resources at terminals was created and sorted according to the developed information attributes framework in Paper 1. To highlight some of the required information attributes from the list, the road hauliers would like the terminal operators to regularly provide their ITU status (e.g. visit code, 'Not released', 'Not discharged', 'Not cleared by customs' and 'No existing pre-notification number') regarding each requested ITU. Whereas a visit code indicates that the ITU is ready to be picked up, the others indicate that the ITU is not ready to be picked up due to the stated circumstance. From the other direction, the terminal would like the road hauliers to provide the ITU ID, ETA and weighing status of all ITUs in order to better plan their arrivals and their access to ITUs to be picked up. (For further information, see Paper 1.) From the comprehensive list, the most relevant information attributes needed to enable effective access to resources at terminals can be selected, exchanged in real time and sorted by applying the information exchange framework developed in Paper 3. In Table 7 (taken from Paper 3), which describes that framework, the rows illustrate how relevant information attributes need to be exchanged depending upon the ITU flows, while the columns show how the relevant information attributes need to be exchanged.

Table 7. Information exchange framework with the most relevant information attributes

<table>
<tr><th rowspan="3">ITU flows</th><th colspan="3">Relevant information attributes to be exchanged</th></tr>
<tr><th colspan="2">… from the road hauliers (request messages)</th><th rowspan="2">… from the Railroad Terminal Operator or Seaport Terminal Operator to the road hauliers (response messages)</th></tr>
<tr><th>... to the Railroad Terminal Operator</th><th>... to the Seaport Terminal Operator</th></tr>
<tr><td>Import</td><td>ITU ID
ETA</td><td>ITU ID
ETA</td><td>ITU status
Queuing status</td></tr>
<tr><td>Export</td><td>ITU ID
ETA</td><td>ITU ID
ETA
Weighing status</td><td>Queuing status</td></tr>
</table>

Different information attributes need to be exchanged depending upon whether the railroad or the seaport terminal needs to be accessed and whether the ITUs need to be imported or exported. For example, when ITUs need to be exported via the seaport terminal, then the road hauliers need to exchange the Weighing status of the ITUs along with other information attributes (e.g. ITU ID and ETA), as elaborated upon in Paper 3.

5.3.3 Required access management services

To identify which of the five identified access management services (see Section 2.2.3) are required to enable effective access to resources at terminals, the services are differentiated in terms of four 'access service elements', to use the language in Paper 2. Despite that name in Paper 2, this thesis instead refers to them as 'access performance indicators', because they double as measures of effective access management herein. As described in what follows, the four access performance indicators are turnaround time, access reliability, access precision and access flexibility. Whereas turnaround time has already been described, *access reliability* (i.e. 'correct access' in Paper 2) means regular correctness of ITUs in the sense that ITUs have been weighed, cleared by customs, released and discharged from the vessel or train; that ITUs are not broken and are in the right sequence and quantity; that all documentation (e.g. internal paperwork and bill of lading) is correct and has been correctly handled; and that the use of resources is correct (i.e. correct number of straddle carriers and workers). By contrast, *access precision* (i.e. 'on-time access' in Paper 2), means that ITUs need to be ready for loading when trucks or trains arrive at the terminal. Last, *access flexibility* means that the actors involved can exchange information updates in real time when changes occur during the terminal or transport processes.

Differentiation allows a comparison of the access performance indicators for each access management service. For instance, different access management services result in different levels of effective access management for road hauliers and rail operators, because a particular service has different effects on the access performance indicators. Considering that dynamic, a differentiation framework is constructed in Paper 2 as a table—in this thesis Table 10—in which the rows represent the access management services, and the columns represent the access performance indicators. An 'X' appears in cells representing access performance indicators affected by access management services. Following the same reasoning, a process analytical framework is constructed in Paper 5, also as a table—applied in Table 8 and Table 9—in which the rows represent the access management services, and the columns represent the terminal and transport processes divided into the three access phases. An 'X' appears in cells representing activities and resources affected by access management services. Paper 3 focused particular on designing and testing a real-time information exchange platform service that was flexible, user-friendly, inexpensive, and developed for small road haulers to enable effective access to resources at terminals.

5.4 RQ3: Effective access management

This section presents the findings from Papers 2, 3 4, and 5 to answer RQ3. As described in Section 1.4, effective access management has three aspects: automatic exchange of the right information at the right time, actors who manage the terminal and transport processes involved effectively and access to the right resources (e.g. specific ITUs, loading bays and entry lanes) at terminals at the right time. As a result, those potential effects can decrease turnaround times for trucks and trains.

5.4.1 Effective automatic information exchange

Paper 4 showcases how effective automatic information exchange can be managed by automatically exchanging the right information at the right time for effective access management. The right information can be identified by the accompanying cost–benefit matrix as the most beneficial, cost-effective information attributes; those attributes are deviation information, direction, driver ID, ETA, goods priority information, ITU ID, ITU status, opening hours, shipment ID and vehicle ID. Unlike the most relevant information attributes, the most beneficial, cost-effective ones are easiest to be collected automatically (i.e. at a low cost) and, at the same time, have great potential for effective access management (i.e. high benefits). Meanwhile, the right time can be calculated according to three time phases: a week before, a day before and two hours before access to specific resources (e.g. ITUs, loading bays and entry lanes) at terminals is granted or received.

The three phases are shown in Figure 10 (taken from Paper 4).

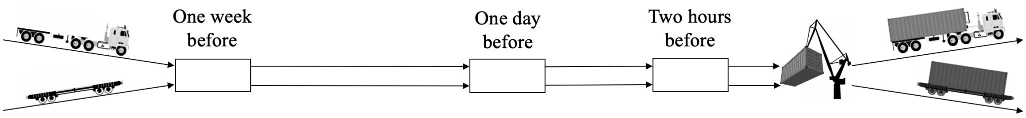

Figure 10. Three phases for automatically sharing the right information

By exchanging information accordingly, access to resources at terminals can be effectively managed. For example, the Seaport Terminal Operator can obtain the necessary information from the road hauliers and the rail operators a week in advance and thus plan the unloading of ITUs from vessels to be correctly placed in the terminal depending upon whether the ITU is to leave the terminal by truck or by train. A day before and, later, two hours before the access of ITUs, the road hauliers or rail operators can send updated information, if necessary, to revise the information sent a week before.

5.4.2 Effective management of terminal and transport processes

This sub-section presents the findings from Paper 5 regarding how the terminal and transport processes involved can be effectively managed by applying access management services and thereby achieve effective activity performance and resource utilisation. However, only the processes in the seaport terminal set-up are analysed here, because the Railroad Terminal Operator neither provides nor plans to provide any access management services.

At the seaport terminal and in road transport processes

Table 8 (taken from Paper 5) clarifies how the terminal and road transport processes in each access phase can be effectively managed by using access management services.

Table 8. Effective management of terminal and road transport processes

Access management services	Terminal and road transport processes		
	Pre-access phase	*Access phase*	*Post-access phase*
Information access services	X		X
Automated gate services		X	
Pre-notification and appointment services	X	X	
Real-time information exchange platform services	X	X	X
Dedicated access services	X	X	X

Information access services in the access phase can help the road hauliers to effectively coordinate their trucks and drivers due to the status information obtained about the ITUs. In the post-access phase, such services can help them to transport the ITUs effectively by lowering the number of unnecessary empty runs. With automated gate services, the time spent by the truck drivers in the access phase can also be reduced, because the manual inspection of ITUs is replaced by sensors and cameras. Moreover, with pre-notification and appointment services, the Seaport Terminal Operator can better plan the placement of ITUs in the pre-access phase, and, in the access phase, the straddle carrier drivers can save time and avoid unnecessary movements at the terminal. Above all, real-time information exchange platform services and dedicated access services can affect the activities and resources in all access phases. The ability to exchange information in real time affords a more flexible range of possibilities to exchange the right information at the right time. If unforeseen events occur in the access phase, then the actors can immediately inform each other and react directly to that information. Last, with dedicated access services, the wait time for truck drivers at the terminal can be eliminated.

At the seaport terminal and in rail transport processes

Table 9 (taken from Paper 5) details how the terminal and rail transport processes in each access phase can be effectively managed by using the access management services.

Table 9. Effective management of terminal and rail transport processes

Access management services	**Terminal and rail transport processes**		
	Pre-access phase	*Access phase*	*Post-access phase*
Information access services	X	X	
Automated gate services		X	
Pre-notification and appointment services	X	X	
Real-time information exchange platform services	X	X	X
Dedicated access services	X		X

With information access services, the rail operators can improve their planning activities in the pre-access phase by virtue of receiving the status information of ITUs. In turn, in the access phase, containers can be loaded more effectively. On top of that, pre-notification and appointment services offer the same advantages as information access services. Meanwhile, automated gate services reduce the need for controllers and shunters, who conduct manual inspections in the access phase but can be replaced by sensors and cameras. In addition, with predefined schedules in hand, the Seaport Terminal Operator can know the arrival times of trains as well as when the ITUs should be placed on the train platform. Another benefit can be realised with real-time information exchange platform services, which allow the Seaport Terminal Operator and the rail operators to exchange the right information at the right time during all access phases, all for effective planning activities that can result in fast loading or unloading activities with short wait times for the train drivers. A final benefit is that dedicated access services can affect the activities and resources in the pre- and post-access phases if the rail operators receive higher priority for certain trains controlled by the Swedish Transport Administration.

5.4.3 Effective access

This sub-section presents the findings from Papers 2 and 3 regarding how access management services can enable effective access to resources at terminals and thus contribute to higher access performance. Briefly put, *higher access performance* means more access performance indicators can be affected: decreased turnaround times, increased access reliability (i.e. access to the right resources), increased access precision (i.e. access at the right time) and enhanced access flexibility (i.e. ability to update other actors when unforeseen events occur). The findings are presented for each service in terms of how it could affect the access performance indicators, at least according to the differentiation framework, shown in Table 10 (taken from Paper 2). As table reveals, access management services able to exchange information in real time yield higher access performance—that is, can affect more access performance indicators.

Table 10. Differentiation of access management services

Access management service	Access performance indicators			
	Turnaround time	*Access reliability*	*Access precision*	*Access flexibility*
Information access services*	X			
Automated gate services*	X			
Pre-notification and appointment services*	X		X	
Real-time information exchange platform services**	X	X	X	X
Dedicated access services**	X	X	X	X

* Developed information sharing, ** Developed information exchange

With information access services, turnaround times can be decreased as long as the road hauliers consider and act upon queueing status information. Automated gate services can also affect turnaround times, because they eliminate unnecessary stops in the seaport terminal, as can pre-notification and appointment services, because the arrivals of trucks at terminals can be arranged so that not all trucks arrive at once. All of those services can also improve access precision, because they furnish the ETAs of trucks and trains, as well as corresponding ITU numbers, to the Seaport Terminal Operator, who can therefore prepare access to ITUs. Beyond that, with a real-time information exchange platform and dedicated access services, turnaround times can be further decreased, because the actors involved can update each other in real time when changes occur in their processes. Against those trends, however, quantitative measurements described in Paper 3 indicated no effect of real-time information exchange platform services on turnaround time, for the truck drivers became stressed while using the services, and the transport planners did not react to the information. Nevertheless, access reliability can be improved when road hauliers receive notices about ITU status throughout the transport and terminal processes involved. Dedicated access services seem to afford the same improvements as real-time information exchange platform services, albeit with the sole difference that truck drivers with dedicated access do not need to queue in order to enter the terminal area.

5.5 Linking the results and discussion chapters

This chapter has presented the results, taken from the appended papers, to answer the research questions on an abstract level by using the overall analytical framework. Although the next chapter, Chapter 6, first discusses the significance of the results on the same abstract level, it gradually shifts the focus of the discussion to a higher level by using the system under study. Therein, from the inferred significance of the results, six propositions are formulated and positioned within the overall analytical framework. Next, the propositions are synthesised into the model of the system under study, at which point the discussion centres on how the propositions can be applied to solve the problems identified in Chapter 1.

6 Discussion

This chapter first discusses the significance of the results as a means to formulate six propositions on an abstract level. Thereafter, it discusses the propositions at a higher level by using the system under study to link them to the problem areas identified in Chapter 1.

6.1 Relationships between the propositions and the overall analytical framework

Each proposition relates to one element of access in the overall analytical framework, as shown in Figure 11.

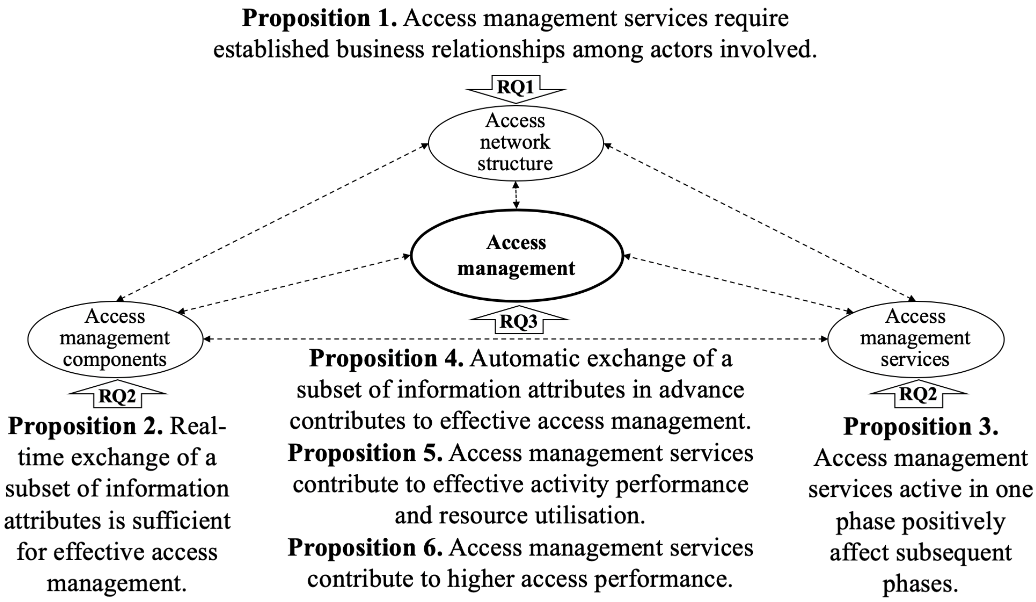

Figure 11. Relationships between the propositions and elements of access in the overall analytical framework

In the following sub-sections, the propositions are formulated and justified in light of the results shown in Chapter 5 (i.e. the findings from the five appended papers) and how those results relate to literature reviewed in Chapter 2.

6.2 Access network structure

The first significant result in this thesis is that business relationships are essential among actors involved if they intend to apply access management services that can enable information exchange in real time (i.e. real-time information exchange platform services and dedicated access services), as discussed in Paper 5. That result corroborates findings in the literature showing that the success of the application of services depends upon the business relationships among actors (Håkansson and Snehota, 1995; Lambert *et al.*, 1998a). The more developed those business relationships are, the more successful the services will be (Seo *et al.*, 2016). A major obstacle to successfully applying services is thus not technology but the human factor (Marchet *et al.*, 2012; Jacobsson, 2019). The business relationships among the involved actors need to be clarified in terms of the interdependencies [i.e., technical, knowledge, social, administrative, and legal

(Håkansson and Snehota, 1995)] to apply access management services that enable real-time information exchange. Thus, the first proposition[2] is:

> **Proposition 1:** Access management services require established business relationships among the actors involved.

Proposition 1 addresses terminal operators, road hauliers and rail operators in particular. It is pointless for terminal operators to implement advanced, costly systems and services if they lack business relationships with road hauliers and rail operators. With business relationships, however, road hauliers and rail operators can influence what services terminal operators implement, which can result in effective access management for all actors involved.

6.3 Access management components

The second significant result is that only the most relevant information attributes (i.e. ITU ID, ITU status, ETA, queueing status and weighing status) need to be exchanged in real time for effective access management (Jacobsson *et al.*, 2017; Jacobsson, 2019). That result challenges the literature on big data, which maintains that as much data as possible should be made visible and analysed (Heilig and Voß, 2017). However, information sources available in intermodal freight transport that can be used to collect information attributes are numerous (Sternberg, 2008; Trafikanalys, 2014; National Heavy Vehicle Regulator, 2015; Jacobsson *et al.*, 2017), and analysing and visualising such a large amount of information in order to predict the future is impractical (Chen and Zhang, 2014). At the same time, collecting, analysing and visualising such vast amounts of information require resources such as skilled analytics, powerful computers and large bandwidths (Chen *et al.*, 2012). Small organisations often lack those resources (Coleman *et al.*, 2016), and 80% of road hauliers in the European Union and the United States are small organisations (Sternberg *et al.*, 2013a). For them, exchanging relevant information is more important than exchanging large amounts of information. For those reasons, the second proposition is:

> **Proposition 2:** The real-time exchange of a subset of information attributes is sufficient for effective access management.

Proposition 2 addresses terminal operators, road hauliers and rail operators. If the last two are willing to exchange relevant information, then the first can prepare access to ITUs and thereby decrease turnaround for trucks and trains.

6.4 Access management services

The third significant result is that access management services, except for automated gate services, can enable information exchange in one access phase and positively affect activity performance and resource utilisation both in that phase and in subsequent phases, as elaborated in Paper 5. To the literature, that result adds the idea that real-time information exchange platform services and dedicated access services can be activated and affect both activities and resources in all phases of access through their abilities to exchange real-time information.

[2] Proposition 1 from Paper 5 is rephrased to align with the form of the other propositions in this thesis.

The ability of such services to update actors involved when unforeseen events occur in the pre-access phase can improve the possibility of granting or receiving on-time access to specific resources (e.g. ITUs, loading bays and entry lanes) at terminals during the access phase (Jacobsson *et al.*, 2018). The result also confirms literature showing that information access services, as well as pre-notification and appointment services, can be activated only during pre-access and reduce wait, loading and unloading times in the access phase (Chen *et al.*, 2013; Phan and Kim, 2015). Therefore, the third proposition[3] holds that:

> **Proposition 3:** Access management services active in one phase positively affect subsequent phases.

Addressing terminal operators, road hauliers and rail operators, Proposition 3 states that knowing which activities and resources can be affected in what access phases is important information for terminal operators when deciding what access management service to apply. The proposition can also motivate road hauliers and rail operators to implement access management services in the pre-access phase as a means to reduce wait times during the access phase.

6.5 Effective access management

The fourth significant result is that the most beneficial, cost-effective information attributes (i.e. deviation information, direction, driver ID, ETA, goods priority information, ITU ID, ITU status, opening hours, shipment ID and vehicle ID) need to be exchanged at three times—a week before, a day before and two hours before access—for effective access management (Jacobsson *et al.*, in press). That result counters previous findings for the same reasoning stated earlier: that smaller organisations lack the resources to collect, analyse and visualise large amounts of information (Coleman *et al.*, 2016) but only a subset of information needs to be exchanged in the first place. The most beneficial, cost-effective information attributes should be selected, because they are most suitable for automatically exchanging information (Jacobsson *et al.*, in press). Thus, identifying certain phases as being necessary not only confirms past findings that providing relevant, timely information is important to local supply chain actors for their planning and coordination activities (Auramo *et al.*, 2005; Kaipia, 2009; Bhakoo *et al.*, 2015; Dubois *et al.*, 2019); they moreover add that those attributes need to be exchanged a week before, a day before and two hours before access to resources in terminal. Thus, Proposition 4 states that:[4]

> **Proposition 4:** The automatic exchange of a subset of information attributes in advance contributes to effective access management.

Proposition 4 particularly addresses terminal operators, road hauliers and rail operators. If those actors can exchange information according to the three required time phases, then they can decrease turnaround for trucks and trains by allowing terminal operators to better prepare for access to ITUs.

---

[3] Proposition 3 from Paper 5 is rephrased to align with the form of the other propositions in this thesis.

[4] Proposition 4 combines the two propositions in Paper 4 and is rephrased to align with the form of the other propositions in this thesis.

The fifth significant result is that access management services can improve activity performance and resource utilisation in the terminal and transport processes involved, as discussed in Paper 5. More activities and resources can be performed effectively with services able to exchange information in real time (i.e. real-time information exchange platform services and dedicated access services) than with services only able to share information (i.e. information access services, automated gate services and pre-notification and appointment services). To the literature, that result adds the idea that different access management services can affect different amounts of activities and resources. It also confirms findings that activities and resources can be performed effectively when access management services are applied. In particular, effective planning and coordination activities can reduce idle times for trucks at terminals (Dekker *et al.*, 2013; Shiri and Huynh, 2016) and thus their turnaround times (Phan and Kim, 2015; Carlan *et al.*, 2016). Beyond that, the effective transport of ITUs can lower the number of unnecessary empty runs (McKinnon and Ge, 2006; Islam *et al.*, 2019), while effective automatic controls by using digital equipment (Heilig and Voß, 2017) can eliminate redundant workforce (Min *et al.*, 2017). Thus, the fifth proposition[5] is:

> **Proposition 5:** Access management services contribute to effective activity performance and resource utilisation.

Directed towards terminal operators, road hauliers and rail operators, Proposition 5 states that ways of improving effectiveness by using access management services is important knowledge for terminal operators when choosing what services to implement, as well as a strong motivation for road hauliers and rail operators to use the services.

Last, the sixth significant result of the thesis is that the access management services can boost access performance. Services that allow exchanging information in real time (i.e. real-time information exchange platform services and dedicated access services) can improve access performance better than ones only able to share information—that is, pre-notification and appointment services, automated gate services and information access service (Jacobsson *et al.* 2018). Enhanced access performance means that access management services can affect more access performance indicators by decreasing turnaround times, improving access reliability, access precision and access flexibility. That result confirms literature showing that turnaround times can be decreased by applying access management services (Phan and Kim, 2015; Carlan *et al.*, 2016; Heilig and Voß, 2017), as well as adds to the literature that services have different capabilities in contributing to decreased turnaround, especially that the reliability, precision and flexibility of access need to be considered when examining access performance. The sixth and final proposition is:

> **Proposition 6:** Access management services contribute to higher access performance.

[5] Proposition 5 from Paper 5 is rephrased to align with the form of the other propositions in this thesis.

Proposition 6 addresses terminal operators, road hauliers and rail operators, none of whom should resist using access management services that can allow them to exchange information in real time. After all, those services can affect more access performance indicators than ones only able to share information.

6.6 Synthesis: Linking the propositions to the system under study and the problem areas

This section links the chapter's discussion and Chapter 1 by uniting the six propositions with the three identified problem areas (i.e. complex network structure, inefficient processes and low level of integration of supportive information components) in the system under study (Figure 2). Based on Figure 2, Figure 12 shows how each proposition links to each problem area.

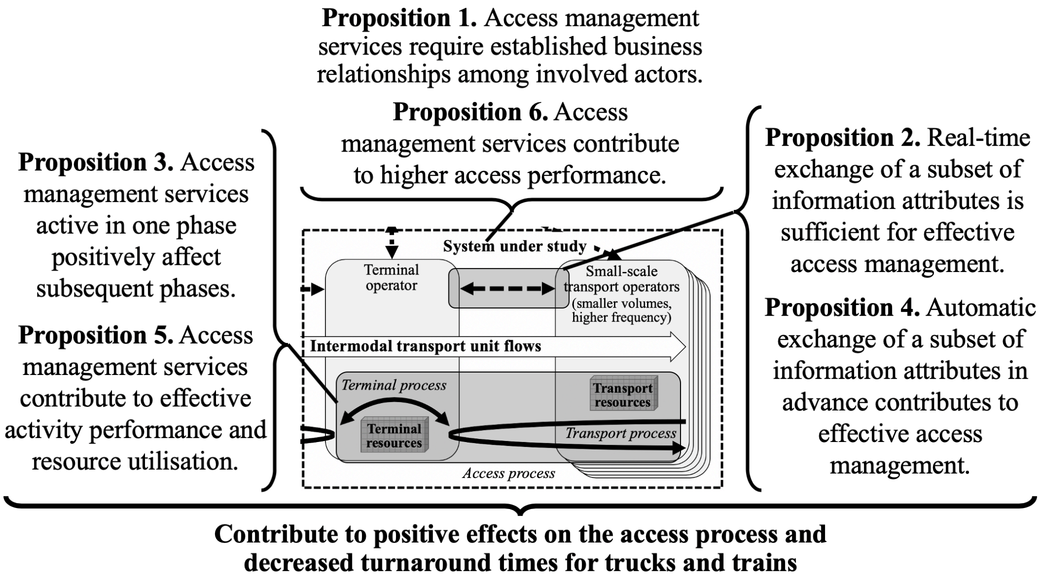

Figure 12. Propositions for the problem areas identified in the system under study

Propositions 1 and 6 address the problems concerning the complexity of the network structure. Though clarification of the interdependencies [i.e., technical, knowledge, social, administrative, and legal (Håkansson and Snehota, 1995)], business relationships among terminal operators, road hauliers and rail operators can be improved. With improved relationships between terminal operators and small-scale transport operators, terminal operators can more easily bridge gaps in differences between the volumes and frequencies of small-scale transport operators (Hultén, 1997) and better handle and manage the large number of such operators (Marchet *et al.*, 2012). Access management services can contribute to improving the access performance indicators by decreasing long turnaround times for trucks and trains (Morais and Lord, 2006; Giuliano and O'Brien, 2007; Ramírez-Nafarrate *et al.*, 2017), by mitigating issues that adversely affect the access process (de Langen and Chouly, 2004; Namboothiri and Erera, 2008; Gharehgozli *et al.*, 2016), by increasing access reliability to the right resources, by increasing access precision to grant or receive on-time access to resources and by increasing access flexibility to enable actors to update each other when unforeseen events occur.

Beyond that, Propositions 3 and 5 address problems with inefficient terminal and transport processes, which themselves relate to poor activity performance and poor resource utilisation (Sternberg *et al.*, 2013b). As this thesis has shown, effective activity performance and resource utilisation can be achieved by using certain access management services. In particular, with the information exchange that such services facilitate, the various actors involved can better plan access, which can lessen the needless movement and stacking of ITUs at terminals (Steenken *et al.*, 2004; Westbroek, 2012; Mutters, 2019), prevent vehicles from arriving unannounced (Covic, 2017; Wasesa *et al.*, 2017) and during peak hours (Maguire *et al.*, 2010), stop vehicles from returning empty from terminals (McKinnon and Ge, 2006; Islam *et al.*, 2013), make loading and unloading more efficient (Sternberg *et al.*, 2013b), reduce unnecessary activities among drivers (Sternberg, 2008; Sternberg *et al.*, 2014) and decrease the paperwork (Heilig and Voß, 2017).

Last, Propositions 2 and 4 address problems regarding the poor integration of supportive information components. Via the real-time exchange of the most relevant information, or with the automatic exchanges of the most beneficial, cost-effective information, the complexity of information exchange (Caris *et al.*, 2013), or deficits in such exchanges (Van der Horst and Langen, 2008; Islam *et al.*, 2013; Wiegmans *et al.*, 2018), can be improved so that it is not inadequate or untimely (Sternberg, 2008), inaccurate or incomplete (Steenken *et al.*, 2004) or prone to conveying insufficient high-quality, real-time information (SteadieSeifi *et al.*, 2014; Acciaro and Wilmsmeier, 2015). Automatic information exchange also offers a cost-effective implementation of solutions to problems regarding the lack of necessary human and economic resources (Stefansson and Lumsden, 2009; Marchet *et al.*, 2012; Evangelista and Sweeney, 2014; Harris *et al.*, 2015). Their implementation also makes the information systems of the actors involved interoperable so that they can overcome setbacks caused by incompatible information systems (Caris *et al.*, 2013), incompatible ICT components (Harris *et al.*, 2015), barriers to adopting new technology (Marchet *et al.*, 2012; Evangelista and Sweeney, 2014) and general distrust in new systems (Cigolini *et al.*, 2016).

Of course, decreased turnaround times for trucks and trains and improved access processes can have other positive effects as well. For one, decreased turnaround lowers environmental impacts by lessening fuel consumption and, in turn, GHG emissions (International Energy Agency, 2019). Fuel use can also be reduced by avoiding unnecessary drives to and from terminals (McKinnon and Ge, 2006; Islam *et al.*, 2013) and by reducing idle running (Do *et al.*, 2016; Phan and Kim, 2016), because truck drivers typically leave their engines running to either cool down or heat up their cockpits during warm or cold weather, respectively. Decreased turnaround times can also lower stress for drivers, who will not agonise over lost driving time and thus experience higher-quality working conditions (Montreuil, 2011). Finally, with decreased turnaround times in terminals, road hauliers can have time to transport more ITUs and reduce costs by requiring fewer trucks and lowering salary costs (Sanchez Rodrigues *et al.*, 2008; Sternberg *et al.*, 2014).

7 Conclusions, contributions and directions for future research

This chapter presents the conclusions and contributions of the thesis, as well as recommendations for future research.

7.1 Conclusions

The purpose of this thesis is to increase the understanding of how access management for road hauliers and rail operators in intermodal freight terminals can contribute to decreasing turnaround times for trucks and trains. *Access management* refers to managing the process by which actors access resources, including specific intermodal transport units (ITUs), loading bays, and entry lanes, at terminals. To that purpose, three research questions were developed, each of which focuses on one of three topics: terminal and transport processes and actors involved in accessing resources at terminals (i.e. RQ1), supportive information components and services required to enable effective access to resources at terminals (i.e. RQ2) and how access to resources at terminals can be effectively managed (i.e. RQ3).

Results regarding the first topic explain the terminal and transport processes studied, the actors involved in those processes and their information exchange. The processes, along with their corresponding activities and resources, have been structured and analysed across three phases terminals: pre-access, access and post-access. Whereas pre-access includes all activities and resources deployed in planning and coordinating access to resources, the access phase includes all activities and resources deployed once access to specific resources (e.g. ITUs, loading bays and entry lanes) at terminals is granted or received. Last, post-access begins after truck drivers have received access to the resources and embarked on their return trips to the road hauliers, at which point the terminal operators finalise any activities involved in the access of resources. However, as the thesis has clarified, though the road hauliers, rail operators and the seaport terminal studied can exchange information, they cannot do so in real time. Meanwhile, between the railroad terminal, the road hauliers and the rail operators, information exchange simply does not occur.

On the second topic, the supportive components required to enable access to resources at terminals include information systems, information communication technology (ICT) applications, the required and the most relevant information attributes. The required information systems and ICT applications are a transaction-processing system and supply chain execution applications, respectively, which can enable automatic, interoperable information exchange. The required information attributes, identified and sorted into a comprehensive list presented in Paper 1, show that the road hauliers, for example, would like to receive regular notifications such as ITU status, which indicates whether an ITU is ready to be picked up. From the other direction, the terminal would like to receive the ITU ID, estimated time of arrival and weighing status of ITUs. From the comprehensive list of required information attributes, the most relevant information attributes to be exchanged in real time were ITU ID, ITU status, estimated time of arrival, queueing status and weighing status.

The required supportive information components can be used to structure and manage five different required information services, referred to collectively as *access management services*. Those required services have been differentiated and listed from most advanced to least advanced in terms of how they can exchange or share information in real time: dedicated access management services, real-time information exchange platform services, pre-notification and appointment services, automated gate services and information access services. Moreover, to measure the effects of those services, four key access performance indicators have been developed: turnaround time, access reliability, access precision and access flexibility. To recap, *turnaround time* begins when a truck or train enters a terminal and ends when it exits; *access reliability* refers to access to the correct resources in the right quantities; *access precision* refers to the provision of access to the right resources at the appropriate time; and *access flexibility* refers to the ability to adapt to unforeseen changes.

The third topic, effective access management, has been analysed in terms of how and when the right information can be automatically exchanged, how access management services can used to effectively manage terminal and transport processes to achieve effective activity performance and resource utilisation and how those services can aid in granting or receiving access to the right terminal resources at the right time, all to decrease turnaround for trucks and trains. The right information can be identified by the cost–benefit matrix in Paper 4 as the most beneficial, cost-effective information attributes (i.e. deviation information, direction, driver identification, estimated time of arrival, goods priority information, ITU ID, ITU status, opening hours, shipment identification and vehicle identification). Unlike the most relevant information attributes, the most beneficial, cost-effective ones are the easiest to be collected automatically (i.e. low cost) and have the greatest potential for effective access management (i.e. high benefits). They need to be automatically exchanged a week, a day and two hours before access to ITUs is possible.

Access management services able to exchange information in real time (i.e. real-time information exchange platform services and dedicated access services) can be mobilised to not only effectively manage terminal and transport processes in order to achieve effective activity performance and resource utilisation (e.g. effective loading and unloading with less movement and lifting of ITUs and fewer drivers, administrators and controllers) but also afford effective access to resources at terminals as a means to boost access performance. *Higher access performance* means that more access performance indicators can be affected: decreased turnaround times and increased access reliability, precision and flexibility. With decreased turnaround times, truck and train drivers can transport ITUs in less time while using fewer trucks and trains, which can lessen fuel consumption.

7.2 Contributions

This thesis makes theoretical and managerial contributions in the domains representing the elements of access in the overall analytical framework, summarised in Table 11.

Table 11. Theoretical and managerial contributions of the thesis

Elements of access	**Theoretical**	**Managerial**
Access network structure	• The dependencies between business relationships and access management services to produce Proposition 1 • The development of the process reference model (Paper 5)	• Business relationships are essential to the successful application of access management services.

Access management components	• The distinction between information exchange and information sharing
	• The development of
	  o The typology reference model (Paper 4)
	  o The information attributes framework (Paper 1)
	  o The information exchange framework (Paper 3)
	• Formulation of Proposition 2
		• Automatic information exchange can be established through interoperable transaction-processing systems and supply chain execution applications.
		• Only the most relevant information attributes need to be exchanged in real time.

Access management services	• The development of the differentiation framework (Paper 2) • Formulation of Proposition 3	• Information exchange can be enabled by using access management services.

Access management	• The definition of access management
	• The development of the cost-benefit matrix in Paper 4, applied to identify the most beneficial, cost-effective information attributes and when they are need to be automatically exchanged
	  o Formulation of Proposition 4
	• The developed process analytical framework in Paper 5, applied to analyse how the access management services can be used to effectively manage the studied processes
	  o Formulation of Propositions 5 and 6
	• The development of the overall analytical framework to synthesise the frame of reference, analyse the findings from the five appended papers that answer the three RQs and structure the six propositions
		• Planning can be improved if the most beneficial, cost-effective information attributes are automatically exchanged a week, a day and two hours before access.
		• The developed frameworks can help with identifying and solving problems with access management.
		• Access management services can help with managing activities and resource effectively and improving access performance.
		• Using improved access services can reduce stress, costs and environmental impacts.

The theoretical and managerial contributions of each element of access are further described in the following sections.

7.2.1 Theoretical contributions

This thesis offers new understandings to the disciplines of intermodal freight transport and information systems by defining *access management*, developing several analytical frameworks and formulating six propositions from its results.

Access network structure
The dependencies between business relationships and access management services have been identified with Proposition 1 ('Access management services require established business relationships among actors involved'). In addition, the process reference model developed in Paper 5 details the activities and resources in the terminal and transport processes studied.

Access management components
The developed typology reference model in Paper 4 illuminates how information can be automatically exchanged between interoperable information systems installed at different actors. The information attributes framework, developed in Paper 4, visualises the current and required information attributes, while the information exchange framework, developed in Paper 3, allows the categorisation of the most relevant information, guides its real-time exchange and differentiates it by whether access to a railroad or seaport terminal is required. As a result, Proposition 2 ('The real-time exchange of a subset of information attributes is sufficient for effective access management') has been formulated.

Access management services
The differentiation framework, developed in Paper 2, can be employed to analyse the provision and use of access management services and the different capabilities of those services for improving access management in relation to the four access performance indicators (i.e. turnaround time, access reliability, access precision and access flexibility). The differentiation framework allowed analysing the results of the two empirical studies and can help to determine which access management service would best improve the access process of certain seaport terminals given their particular customers. From the results, Proposition 3 ('Access management services active in one phase positively affect subsequent phases') has been formulated.

Access management
Along with the definition of *access management*, a cost–benefit matrix has been developed, namely in Paper 4, to identify and structure the required information attributes from Paper 1. The matrix has particularly been applied to identify the most beneficial, cost-effective information for automatic exchange, which resulted in the formulation of Proposition 4 ('The automatic exchange of a subset of information attributes in advance contributes to effective access management'). The process analytical framework, developed in Paper 5, has been used to analyse how the transport and terminal processes involved can be managed effectively by deploying the required access management services. From the analysis, two propositions have been formulated: Proposition 5 ('Access management services contribute to effective activity performance and resource utilisation') and Proposition 6 ('Access management services contribute to higher access performance'). Last, the overall analytical framework captures the essence of access management, allows the analysis of findings from the five appended papers that answer the three RQs and structures the six propositions.

7.2.2 Managerial contributions

The managerial contributions of this thesis should help practitioners to gain an increased understanding of access management.

Access network structure
The ability of actors in an intermodal transport network to apply successful access management services depends upon their business relationships. In short, services that allow exchanging information in real time (e.g. real-time information exchange platform services and dedicated access services) cannot function without business relationships between the actors.

Access management components
Information exchange can be improved if the actors implement and apply both the required interoperable transaction-processing system and supply chain execution applications, which can enable the exchange of the most relevant information attributes. Moreover, the developed analytical frameworks can help decision makers to identify access management problems and resolved them by using access management services.

Access management services
Knowing how access management services active in one access phase can positively affect the activity performance and resource utilisation in subsequent phases is important information for terminal operators when deciding what access management services to implement and apply. Such knowledge can also motivate road hauliers and rail operators to apply access management services in the pre-access phase as a means to reduce wait times during the access phase.

Access management
The access management services can enable effective access to resources at terminals when the most beneficial, cost-effective information attributes are automatically exchanged a week, a day and two hours in advance of access. By exchanging that information at those times, the actor involved can effectively manage the necessary terminal and transport resources to achieve effective activity performance and resource utilisation. Moreover, the access management services can promote high access performance (i.e. decreased turnaround times and increased access reliability, precision and flexibility), which itself can reduce (1) environmental impacts by lower engine idling times, (2) the number of empty runs, which saves truck drivers' time, lowers costs for road hauliers and further reduces environmental impacts and (3) drivers' stress over lost driving time. Decreased turnaround times can moreover allow road hauliers to transport more ITUs per day and reduce the number of trucks and drivers needed.

7.3 Directions for future research

To further develop the frameworks and strategies proposed in this thesis, more quantitative data need to be collected, for only a small amount of such data was gathered during the studies (i.e. time measurements regarding road transport activities only). It would be interesting to quantitatively measure, in both road and rail haulage, the access performance indicators for each access management service as a way to further investigate their impacts. Turnaround times, for instance, can be automatically measured through Bluetooth beacon systems or GPS-tracker systems, whereas the other three access performance indicators require manual measurements. Even so, access reliability, access precision and access flexibility could be measured by having truck or train drivers evaluate their recent access to specific resources in terms of whether such access was correct, was on time and allowed information to be updated if any unforeseen event occurred along the transport route to the terminals.

The strategies and frameworks developed in Paper 4 need to be further implemented so that they can be tested in real-life situations, in which the most beneficial, cost-effective information attributes need be automatically exchanged with respect to the three identified time phases (i.e. a week, a day and two hours before access) between the interoperable information systems of the actors involved. Such exchange needs to be as automatic as possible in order to avoid problems with human factors such as stress and barriers in adopting new technology, as explained in Paper 3. The one-week-before and one-day-before time phases can be implemented without implementing new information systems. Instead, APIs can be implemented to make the information systems of actors involved interoperable. By contrast, the two-hour-before time phase may be triggered manually or by defining different virtual zones, such that when a driver passes by those zones, the information exchange is initiated. Although such zones may be applicable for trains that follow fixed rails, they remain difficult for trucks, which may take different roads to reach terminals. Therefore, future research should investigate how the two-hours-before time phase can be triggered both for trucks and trains.

A limitation of the research is that it focused only on the transhipment of ITUs in road and rail transport, not maritime transport. It also involved investigating only road hauliers, rail operators and terminal operators, not transport coordinators and other transport operators. Therefore, further research is needed that includes other transport modes and actors. Especially interesting would be investigating how information can be exchanged when more actors (e.g. more road hauliers, rail operators, other transport operators and transport coordinators) are involved. In those cases, what would be the best solution that is cost-effective and easy to connect to? Because the information exchange among more actors does not depend upon big data exchange but focuses on the most relevant, most beneficial and cost-effective information to be exchanged, a cloud computing solution may be applicable. To ascertain that possibility, more understanding is needed about how such a system can be implemented and what ICTs need to be included. Because this thesis addresses only some ICT applications for interoperable exchange, it remains to be clarified what ICTs are needed for an easy-to-connect, cost-effective solution that can be used by many actors at once.

Finally, the six formulated propositions should be transferred into hypotheses that can be statistically tested to make the findings statistical generalisable. To statistically generalise the findings, future research should also extend and apply the developed frameworks and strategies in herein to other terminal and transport processes in other set-ups. After all, this thesis considered only a seaport terminal and a railroad terminal, and seaport terminal and road haulage received more attention than the railroad terminal and rail haulage. By following a more inclusive approach, the frameworks and strategies can be further developed and generalised both nationally and internationally.

References

Aastrup, J. and Halldórsson, Á. (2008), "Epistemological role of case studies in logistics: a critical realist perspective", *International Journal of Physical Distribution Logistics Management*, Vol. 38 No. 10, pp. 746–763.

Acciaro, M. and Wilmsmeier, G. (2015), "Energy efficiency in maritime logistics chains", *Research in Transportation Business & Management*, Vol. 17, pp. 1–7.

Almotairi, B., Flodén, J., Stefansson, G. and Woxenius, J. (2011), "Information flows supporting hinterland transportation by rail: applications in Sweden", *Research in Transportation Economics*, Vol. 33, pp. 15–24.

Andritsos, F. (2013), "Port security and access control", in *Fourth International Conference on Information, Intelligence, Systems and Applications (IISA 2013)*, IEEE, Vienna, pp. 1–8.

Anglani, A., Grieco, A., Pacella, M. and Tolio, T. (2002), "Object-oriented modeling and simulation of flexible manufacturing systems: a rule-based procedure", *Simulation Modelling Practice and Theory*, Vol. 10 Nos 3/4, pp. 209–234.

APICS (2019), "Supply chain operations reference model (SCOR)", available at: https://www.apics.org/apics-for-business/frameworks/scor (accessed 3 April 2019).

APM Terminals (2020), "Lifting global trade", available at: http://www.apmterminals.com/ (accessed 12 April 2020).

Arbnor, I. and Bjerke, B. (2009), *Methodology for Creating Business Knowledge*, 3rd ed., Sage, Thousands Oaks, CA.

Arlbjørn, J.S. and Halldórsson, Á. (2002), "Logistics knowledge creation: reflections on content, context and processes", *International Journal of Physical Distribution & Logistics Management*, Vol. 32 No. 1, pp. 22–40.

Auramo, J., Kauremaa, J. and Tanskanen, K. (2005), "Benefits of IT in supply chain management: an explorative study of progressive companies", *International Journal of Physical Distribution & Logistics Management*, Vol. 35 No. 2, pp. 82–100.

Ballis, A. and Golias, J. (2002), "Comparative evaluation of existing and innovative rail–road freight transport terminals", *Transportation Research Part A: Policy and Practice*, Vol. 36 No. 7, pp. 593–611.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99–120.

Baron, M.-L. and Mathieu, H. (2013), "PCS interoperability in Europe: a market for PCS operators?", *International Journal of Logistics Management*, Vol. 24 No. 1, pp. 117–129.

Baumgrass, A., Di Ciccio, C., Dijkman, R.M., Hewelt, M., Mendling, J., Meyer, A., Pourmirza, S., Weske, M. and Wong, T.Y. (2015), "GET controller and UNICORN: event-driven process execution and monitoring in logistics", in *Proceedings of the BPM Demo Session 2015: Co-located with the 13th International Conference on Business Process Management (BPM 2015)*, Springer, Cham, pp. 75–79.

Behrends, S. (2011), *Urban freight transport sustainability: the interaction of urban freight and intermodal transport*, PhD thesis, Chalmers University of Technology, Gothenburg.

Behrends, S., Liljestrand, K., Bäckström, S. and Pahlén, P.-O. (2011), "Intermodal transport from a haulier's perspective", Swedish Intermodal Transport Research Centre, Gothenburg, pp. 1–78.
Bhakoo, V., Singh, P.J. and Chia, A. (2015), "Supply chain structures shaping portfolio of technologies: exploring the impact of integration through the 'dual arcs' framework", *International Journal of Physical Distribution & Logistics Management*, Vol. 45 No. 4, pp. 376–399.
Bisogno, M., Aurelio, T., Antonello, S. and Giancarlo, N. (2015), "Improving the efficiency of port community systems through integrated information flows of logistic processes", *International Journal of Digital Accounting Research*, Vol. 15, pp. 1–31.
Boile, M. and Sdoukopoulos, E. (2014), "Supply chain visibility and security: the SMART-CM project solution", *International Journal of Shipping and Transport Logistics*, Vol. 6 No. 3, pp. 280–292.
Bontekoning, Y.M., Macharis, C. and Trip, J.J. (2004), "Is a new applied transportation research field emerging? A review of intermodal rail–truck freight transport literature", *Transportation Research Part A: Policy and Practice*, Vol. 38 No. 1, pp. 1–34.
Booch, G. (1991), *Object Oriented Design: With Applications*, Benjamin Cummings, Redwood City, CA.
Booth, W.C., Colomb, G.G. and Williams, J.M. (2008), *The Craft of Research*, University of Chicago Press, Chicago, IL.
Bowersox, D.J. and Closs, D.J. (1996), *Logistical Management: The Integrated Supply Chain Process*, McGraw–Hill, New York, NY.
Boysen, N., Fliedner, M., Jaehn, F. and Pesch, E. (2012), "Shunting yard operations: theoretical aspects and applications", *European Journal of Operational Research*, Vol. 220 No. 1, pp. 1–14.
Braden, R.T. (1989), "Requirements for internet hosts: communication layers", Internet Engineering Task Force, available at: https://tools.ietf.org/html/rfc1122 (accessed 12 February 2020).
Bryman, A. and Bell, E. (2011), *Business Research Methods*, Oxford University Press, Oxford.
Buijs, P. and Wortmann, J.C.H. (2014), "Joint operational decision-making in collaborative transportation networks: the role of IT", *Supply Chain Management*, Vol. 19 No. 2, pp. 200–210.
Burke, W.W. (2014), "Changing loosely coupled systems", *Journal of Applied Behavioral Science*, Vol. 50 No. 4, pp. 423–444.
Burstein, F. and Holsapple, C.W. (2008), *Handbook on Decision Support Systems 1: Basic Themes*, Springer, Berlin.
Caris, A., Macharis, C. and Janssens, G.K. (2013), "Decision support in intermodal transport: a new research agenda", *Computers in Industry*, Vol. 64 No. 2, pp. 105–112.
Carlan, V., Sys, C. and Vanelslander, T. (2016), "How port community systems can contribute to port competitiveness: developing a cost–benefit framework", *Research in Transportation Business & Management*, Vol. 19, pp. 51–64.
Chen, G., Govindan, K. and Yang, Z. (2013), "Managing truck arrivals with time windows to alleviate gate congestion at container terminals", *International Journal of Production Economics*, Vol. 141, pp. 179–188.

Chen, H., Chiang, R.H. and Storey, V.C. (2012), "Business intelligence and analytics: from big data to big impact", *MIS Quarterly*, Vol. 36 No. 4, pp. 1165–1188.

Chen, P.C.L. and Zhang, C.-Y. (2014), "Data-intensive applications, challenges, techniques and technologies: a survey on big data", *Information Sciences*, Vol. 275, pp. 314–347.

Christopher, M. (2016), *Logistics & Supply Chain Management*, FT Publishing International, Harlow.

Cigolini, R., Pero, M. and Sianesi, A. (2016), "Reinforcing supply chain security through organizational and cultural tools within the intermodal rail and road industry", *International Journal of Logistics Management*, Vol. 27 No. 3, pp. 816–836.

Coleman, S., Göb, R., Manco, G., Pievatolo, A., Tort-Martorell, X. and Reis, M.S. (2016), "How can SMEs benefit from big data? Challenges and a path forward", *Quality and Reliability Engineering International*, Vol. 32 No. 6, pp. 2151–2164.

Cooper, M.C., Lambert, D.M. and Pagh, J.D. (1997), "Supply chain management: more than a new name for logistics", *International Journal of Logistics Management*, Vol. 8 No. 1, pp. 1–14.

Covic, F. (2017), "Re-marshalling in automated container yards with terminal appointment systems", *Flexible Services and Manufacturing Journal*, Vol. 29 Nos 3/4, pp. 433–503.

Coyle, J.J., Novack, R.A., Gibson, B. and Bardi, E.J. (2015), *Transportation: A Global Supply Chain Perspective*, Cengage Learning, Boston, MA.

Crainic, T.G. and Kim, K.H. (2007), "Intermodal transportation", in Barnhart, C. and Laporte, G. (Eds.), *Handbooks in Operations Research and Management Science*, *Vol. 14: Transportation*, Elsevier, Amsterdam, pp. 467–537.

Creswell, J.W. (2014), *Research Design: Qualitative*, *Quantitative*, *and Mixed Methods Approaches*, Sage, Los Angeles, CA.

Council of Supply Chain Management Professionals (2019), "Supply chain management definitions and glossary", available at: https://cscmp.org/CSCMP/Educate/SCM_Definitions_and_Glossary_of_Terms.aspx (accessed 20 April 2020).

Davenport, T.H. (1993), *Process Innovation: Reengineering Work through Information Technology*, Harvard Business Press, Cambridge, MA.

DB Schenker (2020), "Connect 4.0", available at: https://www.dbschenker.com/global/connect/connect-4-0 (accessed 17 April 2020).

de Langen, P., Figueroa, D.L., van Donselaar, K. and Bozuwa, J. (2017), "Intermodal connectivity in Europe: an empirical exploration", *Research in Transportation Business & Management*, Vol. 23, pp. 3–11.

de Langen, P.W. and Chouly, A. (2004), "Hinterland access regimes in seaports", *European Journal of Transport and Infrastructure Research*, Vol. 4 No. 4, pp. 361–380.

Dekker, R., van der Heide, S., van Asperen, E. and Ypsilantis, P. (2013), "A chassis exchange terminal to reduce truck congestion at container terminals", *Flexible Services and Manufacturing Journal*, Vol. 25 No. 4, pp. 528–542.

DHL (2019), "DHL Global Connectedness Index update", available at: https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/g0-en-gci-2019-update-complete-study.pdf (accessed 17 April 2020).
Do, N.A.D., Nielsen, I.E. Chen, G. and Nielsen, P. (2016), "A simulation-based genetic algorithm approach for reducing emissions from import container pick-up operation at container terminal", *Annals of Operations Research*, Vol. 242 No. 2, pp. 285–301.
DP World (2020), "Innovating to enable smarter trade", available at: https://www.dpworld.com/ (accessed 11 April 2020).
Drucker, P.F. (1986), *Management: Tasks*, *Responsibilities*, *Practices*, Truman Talley Books, New York, NY.
Dubois, A. and Gadde, L.-E. (2002), "Systematic combining: an abductive approach to case research", *Journal of Business Research*, Vol. 55 No. 7, pp. 553–560.
Dubois, A., Hulthén, K. and Sundquist, V. (2019), "Organising logistics and transport activities in construction", *International Journal of Logistics Management*, Vol. 30 No. 2, pp. 620–640.
Dürr, E. and Giannopoulos, G.A. (2003), "SITS: a system for uniform intermodal freight transport information exchange", *International Journal of Transport Management*, Vol. 1 No. 3, pp. 175–186.
Dyer, J.H. and Singh, H. (1998), "The relational view: cooperative strategy and sources of interorganizational competitive advantage", *Academy of Management Review*, Vol. 23 No. 4, pp. 660–679.
Economic Commission for Europe (2001), *Terminology on Combined Transport*, United Nations, Geneva.
Eisenhardt, K.M. (1989), "Agency theory: an assessment and review", *Academy of Management Review*, Vol. 14 No. 1, pp. 57–74.
Elbert, R., Pontow, H. and Benlian, A. (2017), "The role of inter-organizational information systems in maritime transport chains", *Electronic Markets*, Vol. 27 No. 2, pp. 157–173.
Ellram, L.M. (1996), "The use of the case study method in logistics research", *Journal of Business Logistics*, Vol. 17 No. 2, pp. 93–138.
Ellram, L.M. and Cooper, M.C. (1990), "Supply chain management, partnership, and the shipper–third party relationship", *International Journal of Logistics Management*, Vol. 1 No. 2, pp. 1–10.
European Commission (2011), "White paper: Roadmap to a single European transport area towards a competitive and resource-efficient transport system", available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN (accessed 20 April 2020).
European Commission (2019), *EU Transport in Figures: Statistical Pocketbook 2019*, Publications Office of the European Union, Luxembourg.
Evangelista, P. and Sweeney, E. (2014), "Information and communication technology adoption in the Italian road freight haulage industry", *International Journal of Logistics Systems and Management*, Vol. 19 No. 3, pp. 261–282.
Flick, U. (2014), *An Introduction to Qualitative Research*, Sage, London.
Flodén, J. (2007), *Modelling intermodal freight transport: the potential of combined transport in sweden*, PhD thesis, Gothenburg University, Gothenburg.

Gammelgaard, B. (1997), "The systems approach in logistics", in *Proceedings from the 8th Nordic Logistics Conference 1996*, Institut for Logistik og Transport, Copenhagen, pp. 9–20.
Ge, J., Zhu, M., Sha, M., Notteboom, T., Shi, W. and Wang, X. (2019), "Towards 25,000 TEU vessels? A comparative economic analysis of ultra-large containership sizes under different market and operational conditions", *Maritime Economics & Logistics*, pp. 1–28.
Gharehgozli, A.H., Roy, D. and de Koster, R. (2016), "Sea container terminals: new technologies and OR models", *Maritime Economics & Logistics*, Vol. 18 No. 2, pp. 103–140.
Giannopoulos, G.A. (2004), "The application of information and communication technologies in transport", *European Journal of Operational Research*, Vol. 152 No. 2, pp. 302–320.
Giuliano, G. and O'Brien, T. (2007), "Reducing port-related truck emissions: the terminal gate appointment system at the Ports of Los Angeles and Long Beach", *Transportation Research Part D: Transport and Environment*, Vol. 12 No. 7, pp. 460–473.
Giuliano, G. and O'Brien, T. (2008), "Extended gate operations at the Ports of Los Angeles and Long Beach: a preliminary assessment", *Maritime Policy & Management*, Vol. 35 No. 2, pp. 215–235.
Goodchild, A., McCall, J., Zumerchik, J. and Lanigan Sr, J. (2011), "Reducing train turn times with double cycling in new terminal designs", *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2238, pp. 8–14.
Gordon, J.R., Lee, P.-M. and Lucas, H.C., Jr. (2005), "A resource-based view of competitive advantage at the Port of Singapore", *Journal of Strategic Information Systems*, Vol. 14 No. 1, pp. 69–86.
Guba, E.G. (1990), *The Paradigm Dialog*, Sage, London.
Guba, E.G. and Lincoln, Y.S. (1989), *Fourth Generation Evaluation*, Sage, Newbury Park, CA.
Hall, R.W. (2001), "Truck scheduling for ground to air connectivity", *Journal of Air Transport Management*, Vol. 7 No. 6, pp. 331–338.
Halldórsson, Á. and Aastrup, J. (2003), "Quality criteria for qualitative inquiries in logistics", *European Journal of Operational Research*, Vol. 144 No. 2, pp. 321–332.
Halldórsson, Á., Kotzab, H., Mikkola, J.H. and Skjøtt-Larsen, T. (2007), "Complementary theories to supply chain management", *Supply Chain Management: An International Journal*, Vol. 12 No. 4, pp. 284–296.
Hamburg Port Authority (2017), "smartPORT: the intelligent port", available at: https://www.hamburg-port-authority.de/en/hpa-360/smartport/ (accessed 20 April 2020).
Harris, I., Wang, Y. and Wang, H. (2015), "ICT in multimodal transport and technological trends: unleashing potential for the future", *International Journal of Production Economics*, Vol. 159, pp. 88–103.
Heilig, L. and Voß, S. (2014), "A cloud-based SOA for enhancing information exchange and decision support in ITT operations", in *International Conference on Computational Logistics*, Cham, Springer, pp. 112–131.
Heilig, L. and Voß, S. (2017), "Information systems in seaports: a categorization and overview", *Information Technology and Management*, Vol. 18 No. 3, pp. 179–201.

Heinold, A. and Meisel, F. (2018), “Emission rates of intermodal rail/road and road-only transportation in Europe: a comprehensive simulation study”, *Transportation Research Part D: Transport and Environment*, Vol. 65, pp. 421–437.
Hesse, M. and Rodrigue, J.-P. (2004), “The transport geography of logistics and freight distribution”, *Journal of Transport Geography*, Vol. 12 No. 3, pp. 171–184.
Higgins, C.D., Ferguson, M. and Kanaroglou, P.S. (2012), “Varieties of logistics centers: developing standardized typology and hierarchy”, *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2288, pp. 9–18.
Hofer, C.W. (1990), “Toward a contingency theory of business strategy”, in Hahn, D. and Taylor, B. (Eds.), *Strategische Unternehmungsplanung / Strategische Unternehmungsführung*, Physica, Heidelberg, pp. 151–175.
Hogia (2020), “Hogia: fleet management system”, available at: https://www.hogia.com/ (accessed 13 April 2020).
Holweg, M. and Pil, F.K. (2008), “Theoretical perspectives on the coordination of supply chains”, *Journal of Operations Management*, Vol. 26 No. 3, pp. 389–406.
Hultén, L.A.R. (1997), *Container logistics and its management*, PhD thesis, Chalmers University of Technology, Gothenburg.
Huynh, N. (2009), “Reducing truck turn times at marine terminals with appointment scheduling”, *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2100, pp. 47–57.
Huynh, N., Harder, F., Smith, D., Sharif, O. and Pham, Q. (2011), “Truck delays at seaports: assessment using terminal webcams”, *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2222, pp. 54–62.
Huynh, N., Smith, D. and Harder, F. (2016), “Truck appointment systems: where we are and where to go from here”, *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2548, pp. 1–9.
Huynh, N. and Walton, C.M. (2011), “Improving efficiency of drayage operations at seaport container terminals through the use of an appointment system”, in Böse, J.W. (Ed.), *Handbook of Terminal Planning*, Springer, New York, NY, pp. 323–344.
Håkansson, H., Ford, D., Gadde, L.-E., Snehota, I. and Waluszewski, A. (2009), *Business in Networks*, John Wiley & Sons, Hoboken, NJ.
Håkansson, H. and Snehota, I. (1995), *Developing Relationships in Business Networks*, Routledge, London.
IBM (2020), “IBM for travel and transportation”, available at: https://www.ibm.com/se-en/industries/travel-transportation (accessed 12 April 2020).
Ihebom, V., Ekeocha, R. and Fayomi, O. (2019), “Alleviation of drayage truck-entry points congestion in container terminals: a review”, *Journal of Physics: Conference Series*, Vol. 1378 No. 2, Article 022080.
International Energy Agency (2019), “CO2 emissions from fuel combustion”, available at: https://www.oecd-ilibrary.org/energy/co2-emissions-from-fuel-combustion-2019_2a701673-en (accessed 17 April 2020)

Islam, S. and Olsen, T. (2014), “Truck-sharing challenges for hinterland trucking companies”, *Business Process Management Journal*, Vol. 20 No. 2, pp. 290–334.
Islam, S., Olsen, T. and Ahmed, M.D. (2013), “Reengineering the seaport container truck hauling process: reducing empty slot trips for transport capacity improvement”, *Business Process Management Journal*, Vol. 19 No. 5, pp. 752–782.
Islam, S., Shi, Y., Ahmed, J.U. and Uddin, M.J. (2019), “Minimization of empty container truck trips: insights into truck-sharing constraints”, *International Journal of Logistics Management*, Vol. 30 No. 2, pp. 641–662.
Jacobsson, S. (2019), “Potential improvements for access management in intermodal freight terminals: designing and testing a service for small road haulers”, *World Review of Intermodal Transportation Research*, Vol. 8 No. 3, pp. 245–264.
Jacobsson, S., Arnäs, P.O. and Stefansson, G. (2017), “Access management in intermodal freight transportation: an explorative study of information attributes, actors, resources and activities”, *Research in Transportation Business & Management*, Vol. 23, pp. 106–124.
Jacobsson, S., Arnäs, P.O. and Stefansson, G. (2018), “Differentiation of access management services at seaport terminals: facilitating potential improvements for road hauliers”, *Journal of Transport Geography*, Vol. 70, pp. 256–264.
Jacobsson, S., Arnäs, P.O. and Stefansson, G. (in press), “Automatic information exchange between interoperable information systems: potential improvement of access management in a seaport terminal”, *Research in Transportation Business & Management*.
Jeevan, J. and Roso, V. (2019), “Exploring seaport–dry ports dyadic integration to meet the increase in container vessels size”, *Journal of Shipping and Trade*, Vol. 4 No. 1, Article 8.
Jonsson, P. (2008), *Logistics and Supply Chain Management*, McGraw–Hill, Maidenhead.
K2 (2019), “K2: fleet management system”, available at: http://fleet101.com/en/ (accessed 15 August 2019).
Kaipia, R. (2009), “Coordinating material and information flows with supply chain planning”, *International Journal of Logistics Management*, Vol. 20 No. 1, pp. 144–162.
Kovács, G. and Spens, K.M. (2005), “Abductive reasoning in logistics research”, *International Journal of Physical Distribution & Logistics Management*, Vol. 35 No. 2, pp. 132–144.
Kraljic, P. (1983), *Purchasing must become supply management*, Harvard Business Review Press, Boston.
Kroenke, D., Bunker, D. and Wilson, D. (2013), *Experiencing MIS*, Pearson Higher Education, Upper Saddle River, NJ.
Kuehne+Nagel (2020), “Enhancing collaboration across your supply chain”, available at: https://www.kn-portal.com/kn_login/collaboration/ (accessed 17 April 2020).
Kurapati, S., Lukosch, H., Verbraeck, A. and Brazier, F.M. (2015), “Improving resilience in intermodal transport operations in seaports: a gaming

approach", *EURO Journal on Decision Processes*, Vol. 3 No. 3–4, pp. 375–396.

Lam, J.S.L. and Su, S. (2015), "Disruption risks and mitigation strategies: an analysis of Asian ports", *Maritime Policy & Management*, Vol. 42 No. 5, pp. 415–435.

Lambert, D.M. and Cooper, M.C. (2000), "Issues in supply chain management", *Industrial Marketing Management*, Vol. 29, pp. 65–83.

Lambert, D.M., Cooper, M.C. and Pagh, J.D. (1998a), "Supply chain management: implementation issues and research opportunities", *International Journal of Logistics Management*, Vol. 9 No. 2, pp. 1–20.

Lambert, D.M. and Enz, M.G. (2017), "Issues in supply chain management: progress and potential", *Industrial Marketing Management*, Vol. 62, pp. 1–16.

Lambert, D.M., Stock, J. and Ellram, L. (1998b), *Fundamentals of Logistics Management*, McGraw–Hill, Boston, MA.

Larson, P.D. and Halldórsson, Á. (2004), "Logistics versus supply chain management: an international survey", *International Journal of Logistics: Research and Applications*, Vol. 7 No. 1, pp. 17–31.

Liljestrand, K. (2016), *Reducing the environmental impact of food products logistics systems*, PhD thesis, Chalmers University of Technology, Gothenburg.

Lindskog, M. (2012), "Systems theory: myth or mainstream?", *Logistics Research*, Vol. 4 Nos 1/2, pp. 63–81.

Lowe, D. (2005), *Intermodal Freight Transport*, Elsevier Butterworth–Heinemann, Amsterdam.

Lubulwa, G., Malarz, A. and Wang, S.P. (2011), "An investigation of best practice landside efficiency at Australian container ports", in *Australasian Transport Research Forum*, Adelaide, Australia, pp. 1–14.

Lummus, R.R. and Vokurka, R.J. (1999), "Defining supply chain management: a historical perspective and practical guidelines", *Industrial Management & Data Systems*, Vol. 99 No. 1, pp. 11–17.

Lumsden, K., Stefansson, G. and Woxenius, J. (2019), *Logistikens grunder: teknisk logistik [Fundamentals of Logistics]* Studentlitteratur, Lund.

Maguire, A., Ivey, S., Golias, M. and Lipinski, M. (2010), "Relieving congestion at intermodal marine container terminals: review of tactical/operational strategies", in *51st Annual Transportation Research Forum*, Arlington, VA, pp. 11–13.

Marchet, G., Perego, A. and Perotti, S. (2009), "An exploratory study of ICT adoption in the Italian freight transportation industry", *International Journal of Physical Distribution & Logistics Management*, Vol. 39 No. 9, pp. 785–812.

Marchet, G., Perotti, S. and Mangiaracina, R. (2012), "Modelling the impacts of ICT adoption for inter-modal transportation", *International Journal of Physical Distribution & Logistics Management*, Vol. 42 No. 2, pp. 110–127.

Marlow, P.B. and Casaca, A.C.P. (2003), "Measuring lean ports performance", *International Journal of Transport Management*, Vol. 1 No. 4, pp. 189–202.

Marshall, C. and Rossman, G.B. (2014), *Designing Qualitative Research*, Sage, Thousand Oaks, CA.

Mathias, N., Santos, T. and Soares, C.G. (2018), “Analysis of a new container terminal using a simulation approach”, *Progress in Maritime Technology and Engineering*, CRC Press, pp. 43–52.

Maxwell, J.A. (2013), *Qualitative Research Design: An Interactive Approach*, Sage, Thousand Oaks, CA.

McCalla, R.J. (1999), “Global change, local pain: intermodal seaport terminals and their service areas”, *Journal of Transport Geography*, Vol. 7 No. 4, pp. 247–254.

McFarlane, D., Giannikas, V. and Lu, W. (2016), “Intelligent logistics: involving the customer”, *Computers in Industry*, Vol. 81, pp. 105–115.

McKinnon, A.C. and Ge, Y. (2006), “The potential for reducing empty running by trucks: a retrospective analysis”, *International Journal of Physical Distribution & Logistics Management*, Vol. 36 No. 5, pp. 391–410.

Meng, Q., Weng, J. and Suyi, L. (2017), “Impact analysis of mega vessels on container terminal operations”, *Transportation Research Procedia*, Vol. 25 No. 2017, pp. 187–204.

Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. and Zacharia, Z.G. (2001), “Defining supply chain management”, *Journal of Business Logistics*, Vol. 22 No. 2, pp. 1–25.

Min, H., Ahn, S.-B., Lee, H.-S. and Park, H. (2017), “An integrated terminal operating system for enhancing the efficiency of seaport terminal operators”, *Maritime Economics & Logistics*, Vol. 19 No. 3, pp. 428–450.

Mishan, E.J. and Quah, E. (2007), *Cost–Benefit Analysis*, Routledge, London.

Mohr, J. and Nevin, J.R. (1990), “Communication strategies in marketing channels: a theoretical perspective”, *Journal of Marketing*, Vol. 54 No. 4, pp. 36–51.

Mondragon, A.E.C., Mondragon, C.E.C. and Coronado, E.S. (2017), “ICT adoption in multimodal transport sites: investigating institutional-related influences in international seaports terminals”, *Transportation Research Part A: Policy and Practice*, Vol. 97, pp. 69–88.

Montreuil, B. (2011), “Toward a physical internet: meeting the global logistics sustainability grand challenge”, *Logistics Research*, Vol. 3 Nos 2/3, pp. 71–87.

Morais, P. and Lord, E. (2006), *Terminal Appointment System Study*, Transport Canada, Montreal.

Motono, I., Furuichi, M., Ninomiya, T., Suzuki, S. and Fuse, M. (2016), “Insightful observations on trailer queues at landside container terminal gates: what generates congestion at the gates?”, *Research in Transportation Business & Management*, Vol. 19, pp. 118–131.

Mulholland, E., Teter, J., Cazzola, P., McDonald, Z. and Gallachóir, B.P.Ó. (2018), “The long haul towards decarbonising road freight–A global assessment to 2050”, Vol. 216 No. 15, pp. 678–693.

Mutters, N. (2019), *The relation between stochasticity and terminal stacking performance of import containers*, PhD thesis, Delft University of Technology, Delft.

Mymo Terminal (2020), “Helps you digitize loading and unloading procedures”, available at: http://www.mymoterminal.com/home-en/ (accessed 13 April 2020).

Namboothiri, R. and Erera, A.L. (2008), “Planning local container drayage operations given a port access appointment system”, *Transportation*

Research Part E: Logistics and Transportation Review, Vol. 44 No. 2, pp. 185–202.
Naslund, D. and Williamson, S. (2010), " "What is Management in Supply Chain Management? - A Critical Review of Definitions, Frameworks and Terminology," *Journal of Management Policy and Practice*, Vol. 11, Iss. 4, pp. 11 - 28
Natvig, M.K. (2009), "SMARTFREIGHT: a generic approach to ITS for smart urban freight distribution", in *16th ITS World Congress and Exhibition on Intelligent Transport Systems and* Services, Intelligent Trasportation Systems and Services for Europe (ERTICO), Stockholm, pp. 1–7.
Navis (2020a), "Navis: terminal operating system", available at: https://www.navis.com/en/products/terminal-solutions/n4-terminal-operating-system/ (accessed 13 April 2020).
Navis (2020b), "Transforming the ocean supply chain", available at: https://www.navis.com/ (accessed 13 April 2020).
Neagoe, M., Nguyen, H.-O., Taskhiri, M.S. and Turner, P. (2017), "Port terminal congestion management: an integrated information systems approach for improving supply chain value", in *Proceedings from the 28th Australasian Conference on Information Systems*, Association for Information Systems, Hobart, Tasmania, pp. 1–9.
Notteboom, T. and Rodrigue, J.-P. (2009), "The future of containerization: perspectives from maritime and inland freight distribution", *GeoJournal*, Vol. 74, Article 7.
National Heavy Vehicle Regulator (2015), "Performance-based standards", available at: https://www.nhvr.gov.au/road-access/performance-based-standards (accessed 10 June 2015).
Perego, A., Perotti, S. and Mangiaracina, R. (2011), "ICT for logistics and freight transportation: a literature review and research agenda", *International Journal of Physical Distribution & Logistics Management*, Vol. 41 No. 5, pp. 457–483.
Phan, M.-H. and Kim, K.H. (2015), "Negotiating truck arrival times among trucking companies and a container terminal", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 75, pp. 132–144.
Phan, M.-H. and Kim, K.H. (2016), "Collaborative truck scheduling and appointments for trucking companies and container terminals", *Transportation Research Part B: Methodological*, Vol. 86, pp. 37–50.
PSA International (2020), "The world's port of call", available at: https://www.globalpsa.com/ (accessed 11 April 2020).
Ramírez-Nafarrate, A., González-Ramírez, R.G., Smith, N.R., Guerra-Olivares, R. and Voß, S. (2017), "Impact on yard efficiency of a truck appointment system for a port terminal", *Annals of Operations Research*, Vol. 258 No. 2, pp. 195–216.
Reis, V. and Macário, R. (2019), *Intermodal Freight Transportation*, Elsevier, Amsterdam.
Ricci, A. and Black, I. (2005), "The social costs of intermodal freight transport", *Research in Transportation Economics*, Vol. 14, pp. 245–285.
Rodrigue, J.-P., Slack, B. and Comtois, C. (2006), *The Geography of Transport Systems*, Routledge, New York, NY.

Romero, D. and Vernadat, F. (2016), “Enterprise information systems state of the art: past, present and future trends”, *Computers in Industry*, Vol. 79, pp. 3–13.
Roso, V., Woxenius, J. and Lumsden, K. (2009), “The dry port concept: connecting container seaports with the hinterland”, *Journal of Transport Geography*, Vol. 17 No. 5, pp. 338–345.
Sanchez Rodrigues, V., Stantchev, D., Potter, A., Naim, M. and Whiteing, A. (2008), “Establishing a transport operation focused uncertainty model for the supply chain”, *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 5, pp. 388–411.
Seo, Y.-J., Dinwoodie, J. and Roe, M. (2016), “The influence of supply chain collaboration on collaborative advantage and port performance in maritime logistics”, *International Journal of Logistics Research and Applications*, Vol. 19 No. 6, pp. 562–582.
Sharif, O., Huynh, N. and Vidal, J.M. (2011), “Application of El Farol model for managing marine terminal gate congestion”, *Research in Transportation Economics*, Vol. 32, pp. 81–89.
Shiri, S. and Huynh, N. (2016), “Optimization of drayage operations with time-window constraints”, *International Journal of Production Economics*, Vol. 176, pp. 7–20.
Smart Port Community (2017), “SmartPort”, available at: http://smart-port.nl/en/smartport-community/ (accessed 14 March 2017).
SteadieSeifi, M., Dellaert, N.P., Nuijten, W., Van Woensel, T. and Raoufi, R. (2014), “Multimodal freight transportation planning: a literature review”, *European Journal of Operational Research*, Vol. 233 No. 1, pp. 1–15.
Steenken, D., Voß, S. and Stahlbock, R. (2004), “Container terminal operation and operations research: a classification and literature review”, *OR Spectrum*, Vol. 26, pp. 3–49.
Stefansson, G. (2006), “Collaborative logistics management and the role of third-party service providers”, *International Journal of Physical Distribution & Logistics Management*, Vol. 36 No. 2, pp. 76–92.
Stefansson, G. and Lumsden, K. (2009), “Performance issues of smart transportation management systems”, *International Journal of Productivity and Performance Management*, Vol. 58 No. 1, pp. 55–70.
Stefansson, G. and Russell, D.M. (2008), “Supply chain interfaces: defining attributes and attribute values for collaborative logistics management”, *Journal of Business Logistics*, Vol. 29 No. 1, pp. 347–359.
Sternberg, H. (2008), “Transportation visibility and information sharing: a case study of actors’ requirements”, *World Review of Intermodal Transportation Research*, Vol. 2 No. 1, pp. 54–71.
Sternberg, H., Germann, T. and Klaas-Wissing, T. (2013a), “Who controls the fleet? Initial insights into road freight transport planning and control from an industrial network perspective”, *International Journal of Logistics*, Vol. 16 No. 6, pp. 493–505.
Sternberg, H., Nyquist, C. and Nilsson, F. (2012), “Enhancing security through efficiency focus: insights from a multiple stakeholder pilot implementation”, *Journal of Business Logistics*, Vol. 33 No. 1, pp. 64–73.
Sternberg, H., Prockl, G. and Holmström, J. (2014), “The efficiency potential of ICT in haulier operations”, *Computers in Industry*, Vol. 65 No. 8, pp. 1161–1168.

Sternberg, H., Stefansson, G., Westerberg, E., Boije af Gennäs, R., Allenström, E. and Linger Nauska, M. (2013b), "Applying a lean approach to identify waste in motor carrier operations", *International Journal of Productivity and Performance Management*, Vol. 62 No. 1, pp. 47–65.

Stock, G.N., Greis, N.P. and Kasarda, J.D. (1998), "Logistics, strategy and structure: a conceptual framework", *International Journal of Operations & Production Management*, Vol. 18 No. 1, pp. 37–52.

Stock, J.R. and Lambert, D.M. (2001), *Strategic Logistics Management*, McGraw–Hill/Irwin, Boston, MA.

Trafikanalys (2014), "Utveckling av den nationella varuflödesundersökningen" [The development of the national supply chain study], available at: http://trafa.se/PageDocuments/PM_2014_6_Utveckling_av_den_nationella_varufloedesundersoekningen.pdf (accessed 20 April 2020).

van der Horst, M. and de Langen, P. (2017), "Coordination in hinterland chains", in Geerlings, H., Kuipers, B., and Zuidwijk, R. (Eds.), *Ports and Networks: Strategies, Operations and Perspectives* Routledge, New York, NY, pp. 162–177.

van der Horst, M.R. and de Langen, P. (2008), "Coordination in hinterland transport chains: a major challenge for the seaport community", *Maritime Economics and Logistics*, Vol. 10 Nos 1/2, pp. 108–129.

Vinnova (2014), "REACH project", available at: https://www.vinnova.se/p/reach---accesshantering-i-realtid-for-okad-transporteffektivitet-fiffi/ (accessed 20 April 2020).

Vinnova (2020), "DREAMIT project", available at: https://www.vinnova.se/p/dreamit---digital-accesshantering-i-realtid-for-intermodala-transporter/ (accessed 20 April 2020).

von Bertalanffy, L. (1969), *General System Theory: Foundations*, *Development and Applications*, 1st rev. ed., George Braziller, New York, NY.

Wandel, S., Ruijgrok, C. and Nemoto, T. (1992), *Relationships Among Shifts in Logistics*, *Transport*, *Traffic and Informatics: Driving Forces*, *Barriers*, *External Effects and Policy Options*, Studenlitteratur, Lund.

Wasesa, M., Stam, A. and van Heck, E. (2017), "The seaport service rate prediction system: using drayage truck trajectory data to predict seaport service rates", *Decision Support Systems*, Vol. 95, pp. 37–48.

Westbroek, M. (2012), *A conceptual business intelligence framework for the identification, analysis and visualization of container data changes and its impact on yard movement*, Master thesis, Open Universiteit Nederland, Heerlen.

Wiegmans, B., Menger, I., Behdani, B. and van Arem, B. (2018), "Communication between deep sea container terminals and hinterland stakeholders: information needs and the relevance of information exchange", *Maritime Economics & Logistics*, Vol. 20 No. 4, pp. 531–548.

Wiegmans, B.W., Masurel, E. and Nijkamp, P. (1999), "Intermodal freight terminals: an analysis of the terminal market", *Transportation Planning and Technology*, Vol. 23 No. 2, pp. 105–128.

Williamson, O.E. (1981), "The economics of organization: the transaction cost approach", *American Journal of Sociology*, Vol. 87 No. 3, pp. 548–577.

Wolf, C. and Seuring, S. (2010), "Environmental impacts as buying criteria for third party logistical services", *International Journal of Physical Distribution & Logistics Management*, Vol. 40 Nos 1/2, pp. 84–102.

Wong, C.Y. and Karia, N. (2010), “Explaining the competitive advantage of logistics service providers: a resource-based view approach”, *International Journal of Production Economics*, Vol. 128, pp. 51–67.

Woodburn, A.G. (2006), “The non-bulk market for rail freight in Great Britain”, *Journal of Transport Geography*, Vol. 14 No. 4, pp. 299–308.

Wortmann, H., Alblas, A.A., Buijs, P. and Peters, K. (2013), “Supply chain integration for sustainability faces sustaining ICT problems”, in *IFIP International Conference on Advances in Production Management Systems*, Springer, New York, pp. 493–500.

Woxenius, J. (1998), *Development of small-scale intermodal freight transportation in a systems context*, PhD thesis, Chalmers University of Technology, Gothenburg.

Woxenius, J. (2012), “Directness as a key performance indicator for freight transport chains”, *Research in Transportation Economics*, Vol. 36, pp. 63–72.

Woxenius, J. and Bärthel, F. (2008), “Intermodal road–rail transport in the European Union”, Konings, R. (Ed.), *The Future of Intermodal Freight Transport: Operations*, *Design and Policy*, Edward Elgar, Celtenham, pp. 13–33.

Yang, C.-S. (2016), “The antecedents and consequences of supply chain service capabilities in the context of container shipping”, *International Journal of Logistics Management*, Vol. 27 No. 2, pp. 236–262.

Yin, R.K. (2013), *Case Study Research: Design and Methods* (5th ed.), Sage, Thousand Oaks, CA.

Zhao, W. and Goodchild, A.V. (2013), “Using the truck appointment system to improve yard efficiency in container terminals”, *Maritime Economics and Logistics*, Vol. 15 No. 1, pp. 101–119.

Zhou, H. and Benton, W., Jr. (2007), “Supply chain practice and information sharing”, *Journal of Operations Management*, Vol. 25 No. 6, pp. 1348–1365.

Appendices

Appendix A: Participants

The following table describes the participants, including in terms of weekly volume of intermodal transport units (ITUs) processed.

Participant (studies involved in)	Number of employees	Equipment	Weekly volume (in ITUs)
Road Haulier A (Studies 1, 2 and 3)	9	31 trucks	650
Road Haulier B (Studies 1, 2 and 3)	182	50 trucks	300
Road Haulier C (Study 3)	20	50 trucks	300
Road Haulier D (Studies 2 and 3)	60	55 trucks	600
Rail Operator A (Studies 2 and 3)	6	2 trains	1400
Rail Operator B (Study 3)	15	3 trains	1500
Railroad Terminal Operator (Studies 1, 2 and 3)	38	1 ITU crane 2 forklifts	750
Seaport Terminal Operator (Studies 1, 2 and 3)	438	8 ITU cranes 2 railway cranes 40 straddle carriers	10,000
Information System Supplier A (Studies 1 and 2)	33	Fleet management system	N/A
Information System Supplier B (Studies 2 and 3)	5	Application programme interface developer	N/A

Appendix B: Timeline of the research

The research conducted for the thesis formed part of the REACH (Vinnova, 2014) and DREAMIT (Vinnova, 2020) projects. Running from September 2014 to February 2017, the REACH project involved investigating advanced, digital interaction in real time among infrastructures, facilities and vehicles, with the goal of increasing resource utilisation in intermodal freight transport systems by improving access management. By contrast, the ongoing DREAMIT project, beginning in March 2017, has aimed to improve access management for road hauliers and rail operators in terminals, by both facilitating the exchange of digital information and improving the interaction of the actors involved. Both projects have focused on stakeholders in intermodal freight transport systems (e.g. road hauliers, rail operators and terminal operators), who, by using digital technology, can reduce their environmental impact and boost their competitiveness. Involving a university, six large organisations, three small organisations and a public authority, the REACH and DREAMIT projects are also both based on collaboration among academia, industry and society.

The timeline of the three studies and five papers appears in the following table, in which dark grey cells marked with a white "X" indicate that the corresponding paper has been published in an international journal.

	2014		**2015**				**2016**				**2017**				**2018**				**2019**				**2020**	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Study 1																								
Study 2																								
Study 3																								
Paper 1											X													
Paper 2																X								
Paper 3																				X				
Paper 4																							X	
Paper 5																								

Note: X = Published

Even though the studies began and ended at different times, they also overlapped insofar as the knowledge gained in one provided important insights into the others. Likewise, the writing of the papers commenced at different times but overlapped as well. The five papers, each either published in or under review at an international journal, appear in this thesis in chronological order based on their date of publication: Paper 1 was published in February 2017, Paper 2 in June 2018 and Paper 3 in September 2019, whereas Paper 4 was accepted in January 2020 and is now in press, and Paper 5 is currently under review.

Appendix C: Interview guides

Interview Guide 1: Information exchange among participants

A. General

1. Name?
2. What sex?
3. Work position?
4. Describe your work?
5. What does a normal working day for you look like?

B. Information exchange

1. What IT-system do you use today?
2. How is the information exchange coordinated today between the involved actors, resources and activities?
3. Do you receive the desired information today (e.g. information about the arrivals of the vehicles/trains/ships and/or the arrivals of the container/containers)?
   a) If yes, how long time in advance do you receive this information?
      i) How do you receive this information? Analogue (e.g. telephone)? Digital (e.g. IT-system, apps, web services, etc.)
      ii) Do you think that the information is reliable? Do you trust the information?
         (1) If not, how do you think you can better trust or rely on the information you receive today?
      iii) Do you miss anything in the information today?
   b) If not, would you need this kind of information?
4. Do you receive information about the location/locations of the container/containers?
5. How often do the vehicles/trains/ships/containers arrive on time?
6. How often does the information that you receive fit with the reality?
7. Do you receive notification if any changes occur?
8. Do you think that you would be able to plan your resources in a more efficient with an improved information exchange between involved actors?

C. Information attributes

1. What information attributes are available today?
2. What information attributes are missing today (the interviewee gets access to the table with the identified information attributes)?
3. What information attributes would be required to improve the access management?
4. Do you think that you would be able to plan your resources in a more efficient with an improved information exchange between involved actors?

Interview Guide 2: Potential effective management of terminal and transport processes under study

A. General

1. What is your name?
2. What is your gender?
3. What is your position in the organisation?

B. Terminal and transport processes

1. What activities are involved in the terminal or transport processes under study?
2. What resources are involved in the terminal or transport processes under study?

C. Access management services

1. What access management services do you currently use?
2. What access management services do you plan to use in the future?

D. Access network structure

1. What actors are involved in accessing resources at the terminals?
2. How do the business relationships among the actors involved influence the use of the access management services?

E. Effective management of terminal and transport processes

Access management services in current use

a) How have the access management services affected activities in the processes under study?
b) How have the access management services affected resources in the processes under study?

Access management services for future use

a) What are the potential effects of the access management services on activities in the processes under study?
b) What are the potential effects of the access management services on resources in the processes under study?

Interview Guide 3: How access can be effectively managed to decrease turnaround times

A. General

1. What is your name?
2. What is your gender?
3. What is your position in the organisation?

B. Access management services

1. What access management services do you currently apply?
2. What access management services do you plan to use in the future?

C. Effective management of access to resources to decrease turnaround times and enhance other access performance indicators

1. Access management services currently in use
   a) How can the services affect turnaround times?
   b) How can the services affect the reliability of access?
   c) How can the services affect the precision of access?
   d) How can the services affect the flexibility of access?
2. Access management services planned for future use
   a) How could the services affect turnaround times?
   b) How could the services affect the reliability of access?
   c) How could the services affect the precision of access?
   d) How could the services affect the flexibility of access?